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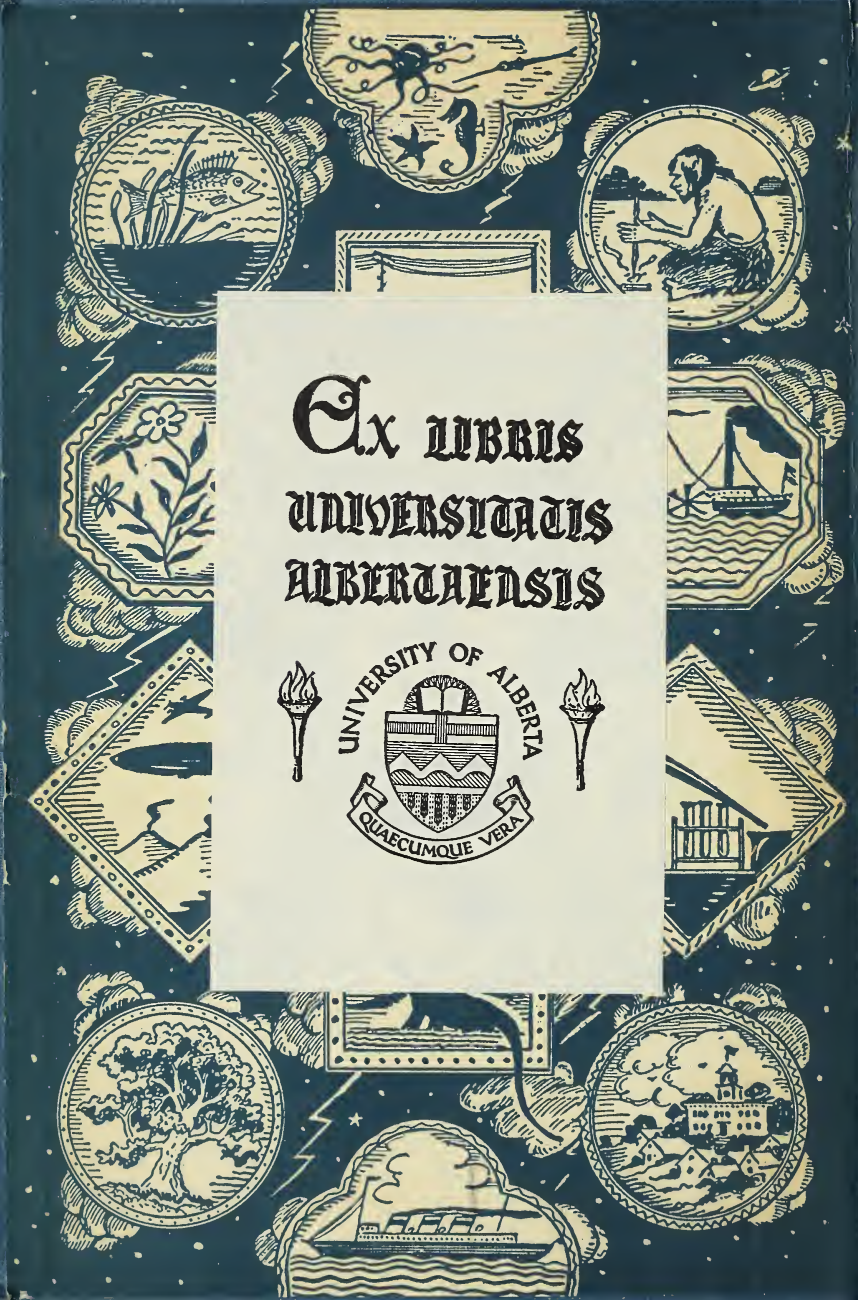
THE MARCH OF SCIENCE



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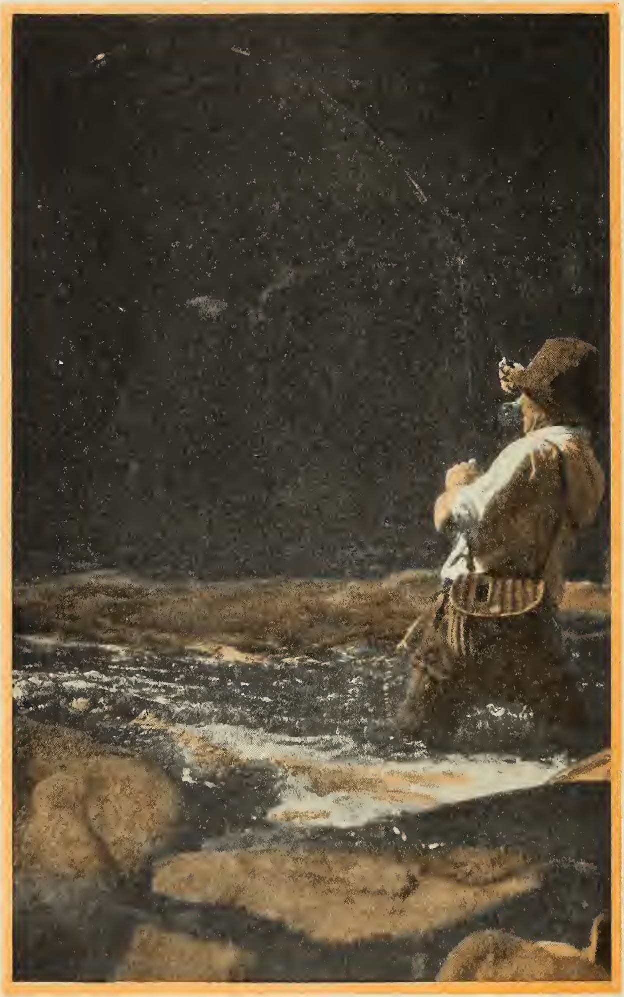

Warren Boyer

Trout fishing remains a favorite form of sport in the modern world. State and national trout hatcheries and game laws, enforced by game wardens, are important parts of our conservation program.

THE MARCH OF SCIENCE V. 3

SCIENCE IN OUR WORLD OF PROGRESS

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FOREWORD TO THE TEACHER

Education and the Changing World. Those of us who have watched the changes in educational methods during the past three decades realize that education is trying hard to be scientific in its attitudes and ideals. Not only are scientists beginning to use the method of science to judge results of their teaching, but teachers of other subjects are doing the same thing. Those of us older in teaching experience sometimes wonder a little at the avidity with which this or that teachers' college advocates methods which under new names are only modifications of similar methods used 10, 20, even 50 years ago. Too many professional schools have come to place emphasis on nomenclature rather than actual differences in teaching in these present days. And yet there is progress in right directions. We are learning to study our children more, and are trying to see things from their viewpoint. We are testing to help the child rather than to make him take "an examination." We are learning that his interests must be consulted if we are to make our teaching result in learning, and best of all in science we are beginning to emphasize the use of facts as tools for learning rather than subject matter to be memorized.

Out of this study of children has emerged the junior high school with its very definite objectives. The spirit of the junior high school is to help children to participate in a world of reality and to guide them to be better school citizens in that world of reality. Its curriculum is used to direct and guide children's activities in such a way that science, civics, language, mathematics, and the fine arts may become co-ordinated and correlated, and not taught as separate *subjects*. They should be integrated into a whole which will lead children, at the most receptive period of their lives, to build attitudes and ideals of good citizenship and sound thinking.

In such a curriculum, science has a very definite position. Not only is it part and parcel of the child's daily activity, but it can, if

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properly taught, lead the child out of superstition and ignorance of laws of cause and effect to a realization of what the scientists' way of looking at things has done and is doing in the world today.

To best make science function at the junior high school level, several things must be done. During those three years children undergo great changes in body, in ability to learn, in attitudes and ways of doing and thinking. Our methods and subject matter must be adapted carefully to these changes. The teaching techniques of the seventh grade must be quite different from those used in the ninth grade. At the seventh-grade level the teacher must use simple language. The science vocabulary should be restricted to the use of relatively simple terms. The experiments and demonstrations should be easy to understand and to perform. The teaching techniques should be adjusted to the levels of the immature youngster of this group. At the eighth-grade level, after a year of exposure to the junior high school activities, our boy or girl comes back to school in the fall with a perspective much enlarged and with a social viewpoint quite different from that held in the previous year. The instruction at this level and the quality of work will therefore be not only at a higher terrace of difficulty, but should be given from quite a different social viewpoint. As the outlook of the child broadens in the third year of the junior high school, a third cycle of science activities will develop at a still higher terrace of difficulty. At this age level the child might transfer his science interests to the wider field of the nation and the world.

The underlying theme for junior high school science should be first, at the lowest level, simple *knowledges* about the interesting and useful science in the immediate environment of the individual. In the second year *understanding* is more the goal, while in the last year *interpretation* and *application* of science are the desired outcomes. The philosophy of presentation should result in the ultimate generalization that man of all the animals is the only one who can control and artificially change his environment. As such, he has dominion over the earth.

Emphasis in science teaching is coming more and more to be placed on method, on problem solving, and the use of science facts in the solution of such simple problems as are within the pupils' comprehension. Although generalizations and fundamental concepts are teachers' goals, they are not so evident to the pupils. Therefore, science courses must lead the child to see and later to understand the reasons for many simple demonstrations and experiments to the end that these understandings will lead to the goal of forming correct generalizations. Mature generalizations are not the immediate goal; it is the forming of these generalizations through science experiences gained through the usage of science materials that makes for the best teaching of science. Moreover these generalizations should be so mastered that they may be used by the student in explaining new science experiences with which he is continually coming in contact. The science generalizations of the seventh grade are thus used in the eighth grade and both series of generalizations are used as a basis for further expansion in the ninth grade. Thus the child's science experiences are made usable and applicable. Science teaching will never function with the mere *learning* of *generalizations;* they must be used and applied intelligently in other science situations.

Our coming social group is bound to have more leisure time as the economic conditions in the future will doubtless make for a substantially shorter working day and more and more time for avocations. The place of science in the junior high school points primarily to adjustment of the pupil to his environment so that he may best use these leisure hours. Interest studies of Curtis show that of 2154 interests mentioned by children, 1305 have to do with earth science and geography, 454 are physical and 368 biological. Hunter's studies indicate more interests in the health phases than are found by Curtis. Science can do much for children in awakening interests and making hobbies worth while. Leisure-time hobbies are important, both for young people and for older ones; collecting, fishing, hiking, keeping pets, gardening, anything that makes for intelligent interpretation and use of the environment.

In this third volume of the series of texts which are organized about the child in his changing world, the emphasis is laid on the place of science in the larger world interests. His growth in perspective during his first two years should make him ready to see the part science has in making his world a safer and better place to live in. Man is the only one of all living creatures who has been able to put his environment to work and who has been able to pass on this social inheritance to the next generation. Science interprets and explains man's control of the air, his knowledge of weather, his use of water power, his use of artificial light in industry, the place of modern transportation and communication, and most important of all, the conservation of our resources of food, living things, and the nation's health. Building on the generalizations made in the seventh and eighth grades, this ninth-grade science, integrated with the social science, physical and economic geography, and health education of this level, should do much to interpret the implications of science in the child's world.

Certain unique features in the series stand out. In the first place, the texts are written from the pupil viewpoint and great care has been taken to present the material so that it may fit the age level of the pupil. Concepts and generalizations grow, and what may be meaningful to the ninth-grade pupil could not be understood clearly by one in the seventh grade; therefore a cyclic plan of treatment is used which is believed to be psychologically sound. Young people are interested in the science of the world around them, not in blocks of a given part of science. As Cox so well says: "A child of the junior high school age lives in a world of things, forces, phenomena, and people. He does not live in a plant and animal world in the seventh year, and in a health world his eighth year, and a physical science world his ninth year." [1]

Emphasis is placed on problem solving and thinking rather than on memorization and reproduction of factual material. Facts are necessary and the development of a fact-finding technique is necessary, but the use of the facts in a purposeful way is of much more importance. To this end the text material is presented as a series of problems which, it is believed, are not beyond the ability of the ninth-grade pupil. Since attitudes of the scientist are very important, many suggestive tests have been added and constant allusions are given to the reasons why scientific attitudes are worth while. A conscious effort is made by the writers to give these reasons of worthwhileness so that transfer of training may take place. The attitudes of suspended judgment, of weighing evidence, and tolerance are certainly worth much more to our future citizens than acquaintance with a host of facts, no matter how important these facts may be.

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[1] Cox, P. W. L., *The Junior High School Curriculum,* Scribner, 1929. By permission of the publishers.

The psychology of the unit with its social aspect is a force which makes for pupil interest and learning. The Morrison technique, with such modifications as have been found desirable, is used throughout the series. Emphasis has been placed upon learning devices and a conscious attempt is made to show the pupil reasons for doing because of the desirable outcomes in transfer of training. While the value of the child's recognition of the big ideas and generalizations in science is seen, the greater importance of properly arriving at these generalizations has been especially stressed in this third book of the series. Numerous devices are used to this end. At the end of each preview, the child is asked to think back to the work done in similar units at lower levels, and a series of generalizations are given him on which he will build the new concepts and generalizations at the ninth-grade level. The problem test at the end of each problem is another help in using facts to reach a definite conclusion or generalization. Use is constantly made of diagrams, graphs, cartoons, and halftones, having legends made with the idea of tying up the visual material with the printed word. The review summary again presents a series of generalizations and the pupil is asked to integrate them into a proper sequence in his review summary outline. Then the practice in problem solving by means of the presentation of the textual material in problematic form; the various types of self-testing exercises, and the many thought questions at the ends of the units are examples of such aids. In addition, constant use is made of the motivation which comes through desirable activities such as those obtained by science clubs and excursions. Leisure-time activities are also used as a means of stressing interest in learning science. These various activities are given relatively more emphasis at this upper grade level because of the opportunities afforded at this level for participation in some of the many social-group activities of the school.

ACKNOWLEDGMENTS

No writer in the field of the modern Junior High School could produce a series of texts without giving acknowledgments to the pioneers of curriculum making whose work has resulted in the evolution of the present-day curriculum. Among this host of names those of Barber, Bayles, Briggs, Carpenter, Charters, Cureton, Cox, Curtis, Frank, Harap, Pieper, and Powers stand out. Many other names might be mentioned, especially the groups who were responsible for the curriculum findings in the Twenty-sixth and Thirty-first Yearbooks of the National Society for the Study of Education. But in spite of their work, the subject matter included in the various courses of study that have been made (and there are hundreds of them) differ widely in scope and aim. But successful courses must be based on the findings of interest studies as well as successful practice of teachers who are practical and pragmatic in their philosophy of teaching. The writers of this text frankly belong to this latter school, and the pages which follow are the results of practical work in the classroom, together with the acceptance of such findings in experimental teaching as best illustrate these objectives.

It would be impossible to name all the teachers who have given help and inspiration to the writers, but the mention of the following must be made because of the personal contacts involved: Dr. Edna Bailey and Dr. Anita Layton of the University of California; Dr. Otis T. Caldwell of Columbia University; Prof. W. L. Eikenberry, State Teachers College, Trenton, N. J.; Miss Winifred Perry, Roosevelt Junior High School, San Diego, Calif.; Dr. Frank M. Wheat, Head of the Department of Biology, George Washington High School, New York City; and Prof. Herbert E. Walter, Department of Zoology, Brown University, Providence, R. I. From each of the above, the writers have had help and inspiration.

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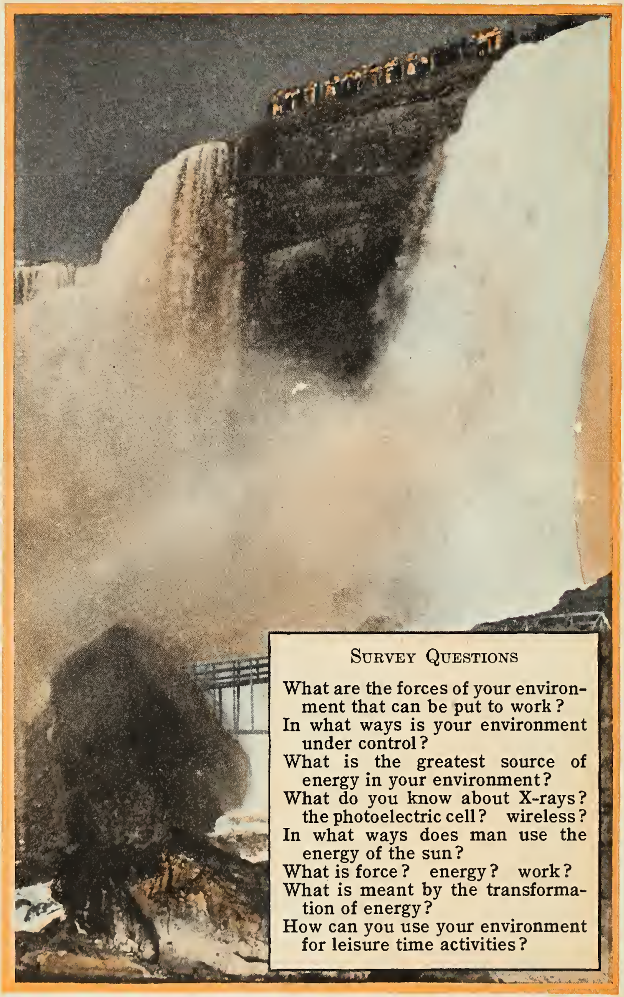


SURVEY QUESTIONS

What are the forces of your environment that can be put to work?

In what ways is your environment under control?

What is the greatest source of energy in your environment?

What do you know about X-rays? the photoelectric cell? wireless?

In what ways does man use the energy of the sun?

What is force? energy? work?

What is meant by the transformation of energy?

How can you use your environment for leisure time activities?

Philip Gendreau

UNIT I

PUTTING THE ENVIRONMENT TO WORK

PREVIEW

Have you ever visited Niagara Falls? Could you ever forget that feeling of awe as you stood on the rocks of Goat Island and watched the mighty waters of the Great Lakes pour over the cliff to crash in thundering clouds of spray which rose below? If you visited the Cave of the Winds, you were buffeted by the air currents and half blinded by the clouds of spray which rose from the falling water. Later on you saw the Whirlpool Rapids and were told that the great gorge through which the Niagara River flows was carved out of solid rock by the force of the running water. Or perhaps, more fortunate still, you may have visited the Grand Canyon of the Colorado and descended into that mile-deep chasm cut out of solid rock by the force of rushing water. As you descended that winding trail into the gorge and saw that the lower part of the canyon, where the walls were almost vertical, was cut out of the hardest kind of volcanic rock, you must have wondered at the force of water that eroded that great gash in the rocks there. Perhaps when you looked at the river below, you thought of the water power that is being wasted there. You may have seen the great hydroelectric stations at Niagara Falls or have visited the Colorado River at Boulder Dam where a start has been made in putting this mighty giant to work for man. Water is a tremendous source of power to the earth, and we see it harnessed, transforming its power into other kinds of energy. Our great hydroelectric plants are examples of such transformations and examples of man's control of his environment. But there is still much power left in water that man has not even begun to utilize. Think of the ceaseless pounding of the waves on the coast. Look at the beach pebbles worn round by this action of the waves. Or think of the force of the tides. In the Bay of Fundy the tides rise as high as 50 feet and rush in with tremendous force twice a day. Here are sources of power that man has hardly begun to use.

If you were interested in science, you doubtless have gone further with your observations concerning the control of the environment. You may have thought of the great storehouses of coal, or gas, which when burned give power, heat, and light. And you may have followed them back to their sources and discovered that they, too, are examples of energy transformed from the sun. For were these fuels not living things many years ago? Or you may have thought of the wind as a source of power. Think of the sailing vessels, or kites, balloons, or gliders, not to speak of windmills which still are a source of power in many parts of the world. Or go to the western mountains and deserts and see the work done by the wind in carving the rocks into fantastic shapes. A forest such as we see in the picture below is mute evidence of the unharnessed power of the wind.

Wright Pierce

A wind-blown forest in the high Sierras. The trees all lie in one direction, showing that a sudden storm uprooted them. In what other ways does the force of the wind change the forests?

Then think of the mineral and soil resources which are being used by man, and of the areas full of coal, oil, iron, copper, silver, and gold which are still untouched. Man in this age of science has harnessed or is using for his benefit most of the factors of his environment, and almost every day sees him making some new application of the use of power.

But there is another natural source of power even greater than that of water. Have you ever thought of an earth without the sun? It is our natural source of heat and light. Unknown to us, its rays are constantly at work on some part of the earth's surface. We do not think of the energy which comes from the sun as the source of all our food, but it is, nevertheless. This magic of the sun acting upon the green substance of the leaf makes life possible on the earth. And when we realize how man has used this power from the sun by planting vast fields of food-making plants and storing up this food for use in winter when plants cannot make use of the sun's energy, we see another example of man's control of the forces of his environment. Or when we realize his use of the forest which came into existence through this same magic of the green leaf and the energy of the sun, and see how many ways this resource is used, we again realize how man utilizes the factors of his environment.

In addition we have not mentioned the almost unexplored field of radiant energy, energy which must come from the sun but which is outside the light spectrum. Our radio, wireless, the X ray, and the photoelectric cell are all examples of man's ability to harness this newly discovered part of the environment.

There is one more use of the environment which to young people is very important and which promises in the future to be even more so. The days ahead evidently are to give us as a nation much more leisure time. As production gets to normal, we shall find that the working day will become shorter and more time will be permitted for pleasures. What are our leisure time activities to be? Are we going to waste that time in loafing about, going to the movies, or just playing, or are we going to make better use of it? There are so many interesting things that our environment offers us: hiking, fishing, camping, hunting, boating, swimming, mountain climbing, nature study, collecting, gardening, and a host of other activities that give both pleasure and health. Some of the suggestions that follow may help you select a hobby which will mean much to you in later life.

Instead of recalling the many science principles and generalizations on the environment and its composition, we are going to make the first problem a review of some of these principles, so that we can start out the year on a firm science foundation. There are certain fundamentals we must all know about energy and matter, and these we will review in the first problem that follows.

PROBLEM I. HOW IS WORK DONE IN THE WORLD?

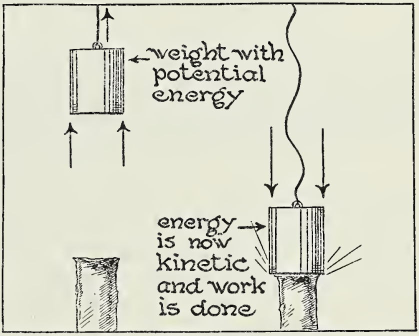
What Are Some of the Forces That We Must Overcome When We Do Work? In our previous study of science, we have found that there are many forces in nature. We have found that air has weight and exerts pressure. We know water exerts tremendous power, for has it not done much to make the land as we know it today? We have seen that gravity, the force which pulls everything toward the center of the earth, also does work. But all of these forces and many others have to be overcome when work is done. You exert force when you throw a stone into the air, but

Photography class of the John Muir Technical High School, Pasadena, Calif.

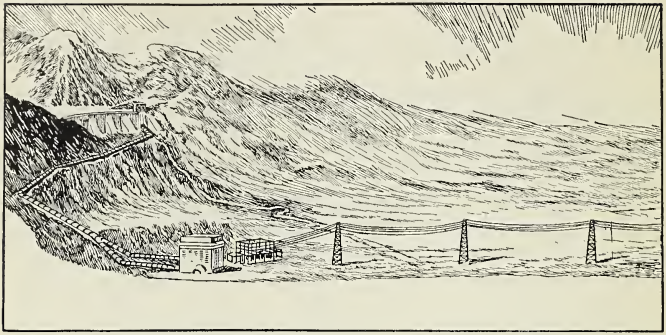
Read your text carefully and then tell in how many ways work is being done by the members of these football teams.

the force we call gravity is greater and so the stone returns to the earth. We can lift a heavy weight successfully, but there are limits to our power. We can successfully stop an opponent in a football game or make a forward pass. In other words, we use force either to stop matter when it is moving, to put matter into motion, or to change the direction of or the speed of a moving body. Force, in the words of the scientist, is a push or a pull.

What Is Energy? Energy has been defined as the ability to do work. Work, as you may recall, is accomplished when any resistance is overcome. *Work is accomplished when matter is moved through space or when moving matter is stopped or its direction of motion is changed. Energy is the ability to do work.* In doing work upon a body, force may be applied to it by pushing it or pulling it. The kind of energy which we are most conscious of is mechanical energy. This is the energy of motion. When the heavy weight of a pile driver is pulled up high into the air, work is done upon it. When it is resting at this high elevation, it has stored within it all the energy that was used in lifting it. The energy possessed by a body by virtue of its position is *potential* energy. Water in a mill pond and the coiled spring in a clock have potential energy. When the weight of the pile driver is released, it falls. Its speed increases as it falls until it strikes the pile which is being driven into the ground. When it strikes the pile, the stored energy is delivered to the pile, but the energy is at that time called *kinetic*. This is all mechanical energy. When the energy is stored in the body at rest, it is called potential or available energy; when the body has energy because of its motion, this energy is called kinetic energy. Heat, light, and electricity may be sent


weight with potential energy
energy is now kinetic and work is done

The weight of the pile driver does work by means of energy. What other examples of two kinds of energy can you give?



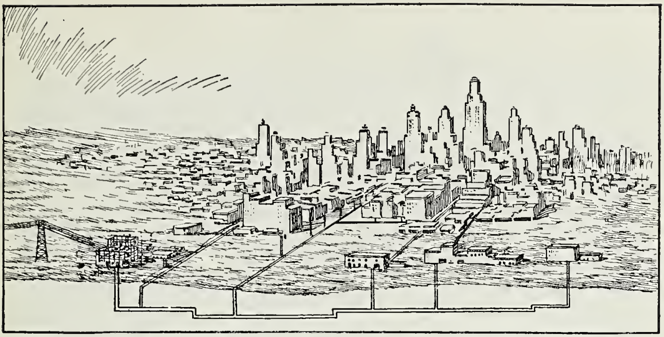
The picture above shows the transformation of energy that takes place in water from a mountain stream as it becomes the light and power of a great city. In the illustration above this water is held back by a dam, flows down through a huge pipe to the penstock of the power plant, where the generator turns the water power into electricity. Then it is stepped up in the transformers shown to the right of the plant, and carried to the outskirts of the city, where it is stepped down again to a voltage usable there.

out across space where there is no matter. They are forms of radiant energy. Chemical action also involves an expenditure of energy. When we heated some red mercuric oxide in a test tube, you may remember we found that a heavy silvery substance soon began to coat the walls of the test tube, while if we tested the gas given off as a result of the heating with a glowing splint, we found the wood burned easily, thus showing that the gas, oxygen, was present. The chemist expresses this chemical change as

$$2\,HgO + \text{heat} = O_2 + 2\,Hg.$$

Hg is the chemical symbol for mercury and O for oxygen. Chemical changes are continually going on in nature and always involve a change in energy.

Transformation of Energy. A scientist takes a piece of coal and says there is energy locked up in it. He calls this potential energy. Other examples of potential energy are water in the lake, electricity in the clouds, wood in the forest, and food on the table. We may dam the lake and let the water fall onto turbines or over a wheel. As the water falls it has power, and this power is transferred to the wheel, which revolves and turns a generator. Electricity is thus generated and passed through wires to the city, where it is used for



Once within the city limits, the electric power is carried in underground conduits and sent to various parts of the city, there to make lights for streets, office buildings, and homes; to turn wheels and give mechanical energy in factories; to aid in the playing of organs or running of radio sets; to give power to new elevators in huge office buildings; or to heat homes or cook meals there. Try your hand at making a summary for your workbook, giving all the transformations of energy that take place from the time the water falls as rain until it is used for various purposes in the city.

lighting the homes and streets, running trolleys, turning machinery, and heating houses. These are examples of transformation of energy. Try to think of other ways in which electricity does work.

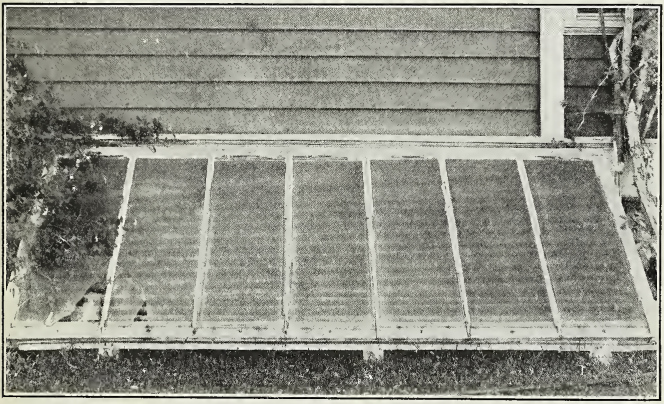
Take, for another example, a field of wheat growing in the sun. The wheat has sprouted but needs energy to push back the grains of soil around it. This energy comes from the food inside the grain of wheat. But soon the wheat plant is many times the size of the original grain of wheat. What has happened is that at first the food in the grain is used, for the wheat is growing larger every day. You must remember that you cannot make something out of nothing. Here a knowledge of botany comes in. Botanists tell us that wheat growing in sunshine takes energy from the sun and this energy causes the green stuff in the leaves of wheat to make food from raw materials taken from the air and the soil. The food is then used by the plant to grow bigger and finally it matures. The wheat is then harvested and eventually may supply food for an army which devastates a region or it may feed a city where all kinds of work is done, or it may be stored in an elevator after harvesting and remain idle for a time. But the energy which the

Asahel Curtis

In what form is energy in this field of wheat? How did the energy get there? In what ways may it be transformed after it leaves the field?

sun supplied is there and can be utilized when the wheat is used. Another series of examples would show the same facts. Our study of energy gives us a statement which seems to be true. It is that although energy can be transformed from one form to another, it can never be created or destroyed. Can you find any examples of this law? Many of our industrial processes depend upon the transformations in energy. Electroplating, refining silver and copper, and the production of some metals from ores are processes which use chemical energy. Chemical action is produced in the plating or refining by means of electrical energy which was in turn produced from mechanical energy, and this mechanical energy if produced by steam came really from chemical energy of a burning fuel. So you see there may be a cycle of energy in almost any manufacturing process in which heat, light, electrical, and chemical energy are interwoven.

Matter and Energy Inseparable in Work. In our world matter and energy are inseparable. It is evident, therefore, that the environment is made up of more than just things or substances, or forms of energy. Energy can work only through the agency of matter. Matter and energy are both prime necessities. Water has been shown to be most important in changing the earth's surface, as well as a source of power. In addition, think of what water means to living plants and animals. The forces of the tides are made use of by the tidal mill, formerly quite common along our eastern coast where the rise and fall of the tide is considerable. The water is matter, but moving water has energy. The power of the air is illustrated in the damage done by wind storms or the many uses of the windmill. Air in motion is a powerful factor, but air is matter and in motion possesses energy. Then we must think of light and the forces liberated through the work of the sun. Think of the solar engines, of a burning glass, of how Californians heat their water by means of a coil of pipes placed under glass on the roof. But we must have matter in the engine, or the pipes, or the glass to make use of the energy. The energy we call electricity plays a much more important part in our environment than it did a few years ago, largely because we have learned more about it. But electricity cannot do work for us



Wright Pierce

In southern California one still finds water heaters of this type. The water heated by the sun is pushed by the incoming cool water into a tank in the kitchen and then goes into pipes which take it over the house. Explain what transformations of energy take place here.

without generators or batteries made of matter. When we consider the photoelectric cell and its work, the use of X rays in photography or the wonders of the radio or television, we realize that the radiant energy has come to be a very important factor in man's environment. But again this energy has to use matter in order to do our work. Matter and energy are inseparable in work.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

gaseous
generates
solid
heat
falling
possible
locked
light
impossible
mechanical
radiant
matter
chemical
liquid
burning
quiet
electrical
transformed
kinetic
work
wheel
released
potential
faucet

Mechanical energy is of two types, (1)____ and (2)____. The energy (3)____ up in a piece of coal is (4)____; the energy (5)____ through (6)____ that same piece of coal is (7)____. This energy can be changed from (8)____ energy into (9)____ energy in a steam engine. From mechanical energy we may get (10)____, (11)____, or (12)____ energy. Energy may be (13)____ from one sort to another; as, for example, the energy of (14)____ water may turn a (15)____ which in turn (16)____ electricity. The electricity may be made to (17)____ or (18)____ factories or even cause (19)____ energy in some manufacturing process. Energy and (20)____ are inseparable in doing (21)____. The energy of the sun must be harnessed to the (22)____ of green plants or in a machine if it is to do (23)____. Energy has to use (24)____ to do (25)____.

NOTE. 1, 2; 10, 11, and 12; 17, 18 are interchangeable.

PROBLEM TEST

In the following activities, name all the kinds of energy involved in the order in which they are used or produced.

1. Lighting a match by striking it on the box.
2. Producing an electric light, starting with burning coal.
3. Heating a flatiron, starting with falling water.
4. Silver plating, starting with a battery.
5. Charging the automobile battery, starting with gasoline.

PROBLEM II. HOW HAS MAN PUT THE FORCES OF NATURE TO WORK?

Uses of Fire. Ever since the beginning of civilization, man has been trying to put the forces of nature to work for him. The primitive man who first used fire discovered it was a powerful servant, and man has been improving on his use of it ever since. Not only does it heat his homes, but it moves railway trains, steamboats, and the wheels of factories. In the motor car it explodes his gasoline. It smelts his metals or moves his motor ships and aids in his chemical processes. We shall see in the pages that follow some of its various uses.

Uses of Water. Man has always used water to drink. He uses it for cleaning his body and to keep its coverings clean. He used it for getting from place to place on rafts or in dugout canoes. Then when larger boats were built, capable of carrying cargoes as well as men, man began to cut canals to shorten distances until we have the barge canal in New York state, the great Panama Canal, the new Mississippi waterway, and now comes the projected Great Lakes waterway, a project that will cost more than the

Galloway

This is the Lake Ontario entrance to the new Welland Canal which is a part of the Great Lakes-to-Gulf waterway. Find out all you can about this project and report to the class.

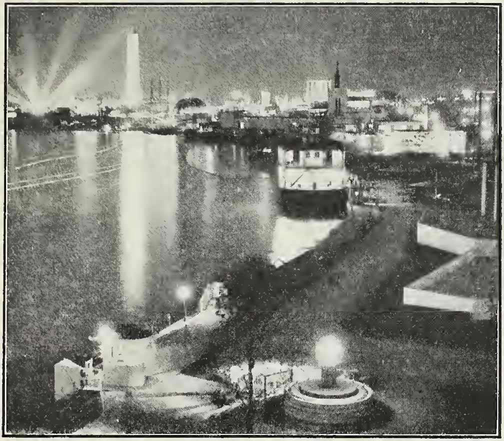
Panama Canal, will give a ship channel 27 feet deep from Montreal through the Great Lakes, and will develop, if needed, 5,000,000 horsepower. Man made early use of the power in water as we know from waterwheels used in earliest civilized times. Since those days what a development of water power has taken place! Today we see great hydroelectric plants such as those at Niagara Falls, Conowingo Dam, or Muscle Shoals and the potential development of the Boulder Dam on the Colorado River with its 1,810,000 horsepower, or the Grand Coulee on the Columbia River with an estimated 700,000 horsepower.

Uses of the Air. Now let us turn to the air. Man early discovered it could do work for him and he used it to turn windmills, to grind corn, and to raise water from the ground, but it took him a long time to discover the air was a substance that had weight and that it could support objects such as balloons, airships, and airplanes. Today we are just beginning to see the uses of air in navigation, and in addition we use it in many other ways. In automobile tires it holds our autos off the ground; it runs our drills, our sand blasts, and sprayers, and allows the building of tunnels and bridges through its compression in caissons.

Uses of the Soil. So we might go on through all the factors of the environment. The use of the soil in agriculture is the earliest

The right side of this field had fertilizer added to the soil. How do you account for the differences in the growth of the clover?

of the industries of man. Year after year conditions of plant growing have been improved until today, if the farmer listens to the advice of the agricultural expert, he is able to raise bountiful crops. He has added nitrogen to the soil through the agency of legumes which he has planted. He has learned how to protect the soil and to work it to the best advantage, and in addition he has come to take from the soil many substances useful in the arts and sciences.



Galloway

Did you see the Century of Progress? It showed the most modern uses of electricity. Some of the later units of this book will tell you what they are. How many can you give now?

Uses of Light. Light has been discovered to have a tremendous bearing on the life of mankind. It is necessary for green plants and to most other living things. We not only use it for growing our crops, thus furnishing food, but also to keep us healthy. In late years we have learned more and more about light and near-light radiations, and now know that they are necessary if we are to keep well.

Uses of Electricity. And what can we say about electricity as a servant? It is relatively a short period in years since the discovery of the Leyden jar in 1746 and Benjamin Franklin's kite experiment in 1752 to the present time. But during this time no other factor of the environment has undergone as great development in its practical uses. Think of living without electric lights, telephone, the telegraph, or the radio. Think of the part electricity plays in transportation and of its uses in industry and science. And yet all of these things have come almost within the lifetime of the writers of this book.

Uses of Radiant Energy. When we come to the uses of the energy which we call radiant energy, then we have the most wonderful developments of all. We may not be able to understand the latest concepts of matter as energy, but we are aware of the wonders of radium, of the X ray, and of the photoelectric cell. And now with almost every home having its own radio set, we have at least to take notice of these newest of all discovered forms of energy. The units which follow will help to give you a little idea of at least some of the uses of modern science in these factors of our environment, many of which are so newly discovered. We may realize after we have finished this year's course the significance of the statement, "We live in an age of power."

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

airplanes
hydrogen
radiant
machines
power
work
fire engines
disease
nitrogen
compressed
X
drunk
Y
understand
forces
water
health
photo
carbon
ray
electricity
navigation
misunderstand
heat

Man since early times has made the (1)____ of nature (2)____ for him, although it is only recently that he has begun to (3)____ much about them. Man has used fire for (4)____ since early times, but only recently for (5)____. Man has always (6)____ water and used it for (7)____, but again only recently has he developed (8)____ from it to run his (9)____ and to light and heat his homes by (10)____ generated by it. The air holds up his (11)____ and runs his (12)____ air (13)____. The soil has come to be scientifically used and (14)____ from the air is added to it. Much has recently been discovered about the (15)____ values of radiant energy. Of all the forms of radiant energy of use to a physician, the (16)____ ray has been of the greatest practical value.

PROBLEM TEST

Classify the matter and the energy involved in producing the following activities. Tabulate your answers under the headings.

1. The driving force of a motor car.
2. Production of food in a plant.
3. A boat floating down stream.
4. Reading a book by electric light.
5. Drawing water with a windmill.
6. Pumping water from a well by hand.
7. The rising mercury in a thermometer placed in sunlight.

	Natural		Artificial	
	Matter	Energy	Matter	Energy
1.				
2.				
3.				
4.				
5.				

PROBLEM III. WHAT ARE SOME OF THE RECREATIONAL ADVANTAGES OF OUR ENVIRONMENT?

Differences in Environment Make Differences in Recreations. Someone has said, "All work and no play makes Jack a dull boy." Our present-day Jacks and Jills do not find much difficulty in having time for play. Sometimes they have so much time they do not know how best to use this leisure. This problem will give you some suggestions as to how best to use the environment for worth-while recreations.

In the first place, much depends on where we live. The boy or girl who lives in the country has some advantages over his city cousins. On the other hand, the city offers many more recreational advantages in swimming pools, playgrounds, parks, good libraries, free illustrated lectures, museums, and art galleries.

Wright Pierce *Brown Bros.*

How does the environment control your recreations? Which of the two types of recreation do you prefer?

But when we consider the natural environment, then we have better advantages for hiking, camping, bathing, fishing, hunting, gardening, or collecting in the country. But with the auto used by almost every family, it is not difficult to make use of our natural environment. Let us see what some of the things are that are really worth while doing.

Gardening. Here is an avocation that can be practiced in the city as well as the country. For what is prettier than a window box and what is more interesting than an experimental school garden, even if it is in a schoolroom. Not only can one raise flowers, but he can also apply, practically, a good deal of science he has learned. Gardens can be run for profit and the family vegetables raised there, or we can use them as experimental plots. In many parts of the country tracts of land have been set aside for school gardens with great success. You can get practice in grafting and budding; you can plan and build a hotbed and a cold frame, and perhaps get a group from the science club to plan for planting and beautifying the school grounds.

Warren Boyer

How many of you can do the "stunts" shown here? Do not try them unless you know how to swim. Do you know why?

Boating and Bathing. Everyone should know how to swim and be able to practice life saving. Canoeing, rowing, and sailing are real sports which involve a good deal of knowledge of science. Do you, for example, know what the center of buoyancy in a boat is? Or do you know how to find out its displacement? Do you know how to tack a boat or how to work your way upstream in a canoe? Some of these science questions are answered in the pages which follow.

Hiking. Here is a sport that has a good many attractions. We can have as our objective just exercise and perhaps visit some near-by point of interest where we can get a good view or go swimming or play games. But how much more interesting is a nature hike or a collection trip! We can get up bright and early and go on a bird hike. Here we need an opera glass and some means of identifying the birds we see. A set of Audubon bird cards can be obtained from the American Audubon Society and will be found most useful. Keep a bird calendar and keep track of the birds you see. Or you can make as your objective the collecting of living things for the school aquarium or vivarium. Look up pages 270 to 305, *My Own Science Problems*, for suggestions as to how to go to work. Perhaps some of you who have a camera will want to make photographs to illustrate the "high spots" of your hike. A collection of prints to show the various land or rock forms which you find would make a fine exhibit on the bulletin board. Some of you may prefer to collect rocks or minerals. Usually some members of the science club will want to make collections and get duplicates which they can exchange for others that they do not have. You can make wooden trays for your specimens, and label each specimen, giving its name, date of collection, and place where it was found.

A group of hikers in Mount Rainier National Park. Have you ever climbed a mountain?

Mountain Climbing. Here is real sport. While you may not climb the Alps or the sharp peaks of the Sierras, you can usually find mountains or hills in your neighborhood which will give you worthwhile views and perhaps a bit of a scramble over the rock near the summit. And what a thrill it is to really conquer the summit and enjoy the panorama stretched out at your feet! Mountain climbing should not be attempted alone, and this is true of any long hike into unfrequented places. Accidents may happen, and at such times you need help. Never try difficult rock climbing without a rope and a companion.

Camping. No one has really known the outdoors unless he has made a camp in the woods or on the shore and had the experience of knowing that he will either be very comfortable or uncomfortable for the night, depending on whether he knows how to make a good camp or not. We have to choose our camp site so that we shall be dry if a storm comes up; we have to know how to make a fireplace and build a fire; we must know how to cook, as well. But if one has had this experience of having to depend upon his own ingenuity to be comfortable, it is worth a lot. Camping teaches self-reliance, comradeship, and, above all, sportsmanship. We often hear of the dangers of being lost in the woods without food or shelter. A boy scout does not fear this predicament, for he has had training in wood craft. It is foolish to go into the forest without a compass and without knowledge of the trails; with these no boy or girl ought to fear the woods. There are so many things of interest there, birds, wild furry animals, trees, bushes, strange wild flowers, and stranger fungi; all are interesting if we know something about them.

Fishing and Hunting. Here is a recreation that to some of us is the greatest sport of all. It requires skill to be a crack shot or to throw a fly, but once we have acquired that skill, we never forget it. What is more sport than to fly-fish a stream for trout? You must match your wits and skill against the trout, and once you hook him, if you use light tackle, your fish has as much chance as you do. Fishing develops true sportsmanship. The real sportsman is a conservationist. He does not fish and hunt to see how much he can destroy. He does it to match his ability with that of the fish or game that he is seeking. I doubt if any true sportsman ever felt badly to see a big trout get away, provided that the trout outguessed and outfought him. Fish and hunt if you can, but do it like a good sport. Obey the game laws and help others to do the same. Join the Junior Isaak Walton League and help its program of conservation. And, above all, learn when on the stream or in the woods to be always on the lookout for some of the many interesting things you will find there, for half the fun of being in the open is to know the habits of those friends in feathers, scales, and fur who inhabit the forests you hunt in and the banks of the streams you fish in.

Courtesy U. S. Forest Service

A vacation like this is inexpensive. What advantages has this camp site?

Our Heritage of National Parks. This government of ours has spent some of its money wisely when it set aside the many national parks to be public playgrounds and centers for conservation of wild life. There are all together 22 national parks in this country and 18 in Canada, most of them being in the western part of the country. The Yellowstone, with its famous geysers and hot springs; Glacier, with its wonderful mountains and splendid fishing, and Yosemite, with its deep valley, are the best known. In addition to these areas, most of the great irrigation reservoirs are natural homes for game fish and are rapidly being used as playgrounds for people who live near them. Fortunately for those of us who live in the east, many states have now begun to realize the value of state reservations and state forests where wild life can be undisturbed and where people may come and enjoy the outdoors. Many states and some cities have public camp grounds, and all through the west we find them with many conveniences for the camper. If you want to know more about some particular park, write to the National Park Service, Department of the Interior, and ask for information. It will be sent to you free of charge. Or if you are interested in fishing, send to the Bureau of Reclamation, Department of the Interior, and ask for their pamphlet *Federal Irrigation Reservoirs as Pleasure Resorts.*

© *Hileman*

Two Medicine Lake, Glacier National Park. The tents at the right are on the public camp ground. This lake contains many large and gamy trout and can be fished from the shore, while there are many interesting trails on the shores for the hikers. Do you have any National Parks or forest areas in your vicinity? Do you use them?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

ability
climbing
parks
work
boating
collecting
11
use
irrigation
44
natural
lakes
fishing
forest
mining
recreation
22
hunting
sportsmanship
33

There are other ways to (1)____ our environment than to make it (2)____ for us. We can use it for (3)____. Some of the leisure time activities afforded to us by our (4)____ environment are swimming, (5)____, gardening, (6)____, hiking, mountain (7)____, camping, (8)____, and (9)____. In almost all of these recreations good (10)____ is essential. We not only have the outdoors for these recreations, but we also have a great system of (11)____, national (12)____ and many state and national (13)____ areas where camping, fishing, and hiking can be had. For fishing there are many new (14)____ reservoirs which furnish excellent sport.

NOTE. Numbers 5, 6, 8, and 9 are interchangeable.

PROBLEM TEST

You are fly-fishing for trout alone, and have caught your limit of fish. Just as you are about to leave the stream, you see a big trout rising for flies. Which of the following things should you do?

1. I should throw one fish from my basket away so as not to have a limit, and go after that trout.
2. I should try to catch it and if I do catch it, then throw away a small fish and keep the big one.
3. I should go home, for I have caught my limit of fish.

Check the reasons for your answer below:

1. A good sportsman does not disobey the law.
2. I should be within the law if I threw away one fish and tried for another.
3. I should be within the law if a game warden should come up after I had thrown away the small fish from my basket.

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned. These big ideas we call generalizations. Some of the generalizations and facts that should be included in your summary are the following:

1. Force is a push or a pull of another force against matter.
2. Work is done when matter is moved or when moving matter is stopped.
3. Energy is the ability to do work.
4. Energy stored in a body is potential. When released producing motion, it is kinetic energy.
5. We use mechanical, heat, light, chemical, and electrical energy.
6. Energy may be transformed from one kind to another.
7. Energy can never be destroyed or created.
8. Matter and energy are inseparable in work.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × $2\frac{1}{2}$.*

I. **Force in science means:** (1) violence; (2) physical vigor; (3) a push or a pull; (4) any action between two bodies that tends to change their relative positions; (5) gravity.

II. **Energy in science means:** (6) strength; (7) power forcibly exerted; (8) capacity for doing work; (9) authority; (10) ability to do work.

III. **Energy may be:** (11) mechanical; (12) the energy possessed by a body by virtue of its position or potential; (13) chemical; (14) specific; (15) kinetic, or energy of a moving body.

IV. **Energy may be transformed from one form to another when:** (16) we light a match; (17) we go upstairs; (18) we knock a man down in playing football; (19) I write these words; (20) we move a heavy weight.

V. **Matter and energy are inseparable when we do work, as is proved when:** (21) an X-ray picture is taken; (22) the waves rush up on the beach; (23) wind holds up a kite; (24) a plant absorbs water; (25) we turn on the radio.

VI. **Examples of how man has put the forces of nature to work are seen in:** (26) the unused oil in the California oil fields; (27) the projected Great Lakes waterway; (28) the work done in making food by forest trees; (29) the photoelectric cell when it opens a door; (30) the use of coal to run a locomotive.

VII. **The natural environment furnishes us with opportunities for:** (31) going to the movies; (32) playing cards; (33) hiking; (34) trout fishing; (35) swimming and boating.

VIII. **A good sportsman will:** (36) always play fair; (37) never take more than his limit; (38) be a conservationist; (39) tell true fish stories; (40) cheat if he can do it without being found out.

PRACTICAL PROBLEMS

1. Distinguish between potential and kinetic energy, giving as many examples as you can.
2. Distinguish between matter and energy and give examples.
3. What are five different kinds of energy which occur in nature? Give an example of each.
4. Plan a hiking-camping trip into an unfamiliar mountainous region for two people for a week. What will be your equipment and give reasons for it?
5. If you caught a poacher using dynamite in a stream where there were trout and he offered to give you some trout if you'd keep quiet, what would you do?
6. What opportunities are there for a city dweller to grow plants?
7. How can one study birds if he lives in a large city?
8. What are some precautions one should take when hiking, mountain climbing, or camping?

LEISURE TIME ACTIVITIES

1. Visit some manufacturing plant in your locality and see in how many different ways they use power there.
2. Make a survey of your home to discover what kinds of energy are being used and whether they are used there during 24 hours.
3. See how many different times you transform energy in a day's work.
4. Try some experiment in which you use heat energy to get mechanical energy. Set it up and demonstrate it before the class.
5. Try making casts of bird tracks. (See pages 29–33, Mann and Hastings, *Out of Doors.*) You can make a pair of book ends, using leaf prints or animal tracks as decorations.
6. Make a snake cage and see how many kinds of harmless snakes you can collect in your locality.

7. Study the spawning habits of some fish, like the sunfish or stickleback, found in most streams and ponds.

8. Make a spreading board, then spread and mount your collection of moths or butterflies.

9. Get such a book as Loomis' *Fieldbook of Rocks and Minerals,* and make a classified collection of the rocks and minerals in your locality.

10. Start a nature collection of some kind. For suggestions see *Making Nature Collections,* Service Library, series D#3198, Boy Scouts of America 1929.

11. Learn to cast a fly for accuracy and distance.

SCIENCE CLUB ACTIVITIES

1. Plan a club visit to some manufacturing plant. Let each member take some process or part of the plant to report on and later hold a meeting at which the visit will be discussed by members of the club.

2. Take a nature hike and bring back examples of life found on the trip. Remember, not more than one specimen of uncommon plants or animals should be taken. An exhibit may be planned to show the results of your trip.

3. A good project for your club would be to make a nature trail. For suggestions, read Carr, *The Nature Trail Book,* Oxford University Press, 1932.

4. Plan an indoor nature trail to be set up in your laboratory. For directions see Mann and Hastings, *Out of Doors,* page 366.

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SURVEY QUESTIONS

How do you differ from the lower animals?

How can you change your environment?

Why is it that man has been able to improve his environment when the lower animals cannot do this?

How have shelters changed since the time of the savage until now?

What modern inventions would you classify as the most important?

What are some of the attitudes of a scientist?

Frank Bauer by R. I. Nesmith and Associates

UNIT II

MAN ALONE CAN ADAPT THE ENVIRONMENT TO HIS NEEDS

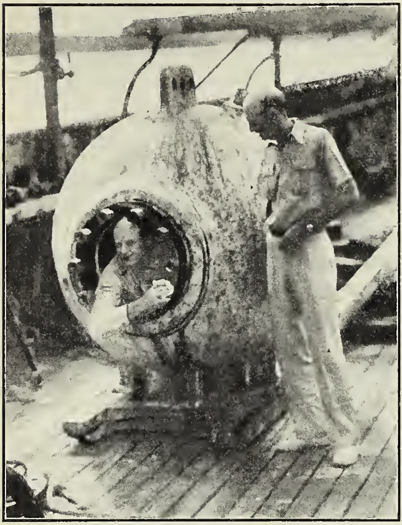
PREVIEW

If we compare the lives of the lower animals with man, we are struck by one great difference. Man has been able, because of his greater adaptability and intelligence, to change his environment so that he is practically independent of it. Not so with the lower animals. Fish live in the water and cannot live anywhere else. They are fitted for this life because of their gills, which enable them to take oxygen out of the water, and because of their streamlined body with fins as organs of locomotion. Very rarely are fish seen outside their habitat of water. The flying fish and the climbing perch of the tropics do indeed leave their watery home for brief periods, but they must return to the water if they are to live.

Birds, although they may migrate long distances and thus change their environment, apparently do not do this to escape cold or to get food, but rather respond to an urge which results in the laying of eggs and the rearing of young. Birds build nests, but they cannot be said to give them much protection from the elements. Birds have conquered the air, but they are still creatures of their environment.

Even the highest of the animal kingdom, the group we call mammals, are still creatures of their environment. Place the polar bear or Arctic husky in a temperate environment and it will suffer and often die. Tropical fish, as you know, must be kept in heated aquaria if they are to live. Case after case might be given to show that most of these animals, although some are quite intelligent, are totally unable to adapt themselves to a changed environment or to change the environment to their needs. A few animals build shelters or dens, and some insects make elaborate nests, but we always find them dormant during the cold weather. They have not gained control over their environment.

On the other hand, man is practically independent of his environment. He has learned to go under the water and stay there. Beebe, in his bathosphere, has gone down into the ocean depths for over half a mile and the balloonists have explored the stratosphere to a height far exceeded by any bird. Man, in airplanes, can soon outfly and outdistance a bird. The aviator is able to go to altitudes where he takes his oxygen along with him. When it comes to combating cold, man has made buildings of steel, concrete, stone, or wood, with elaborate heating and lighting systems, so that the length of day or low temperatures have little effect. Man changes his clothes to meet the temperature changes, so here again he controls the environment.



Wide World

Have you read William Beebe's *Half Mile Down?* It will tell you of his explorations in this bathosphere.

In the unit that follows there are some generalizations that we have reached in our earlier study of science that will be useful to recall at this time. Here are some of them:

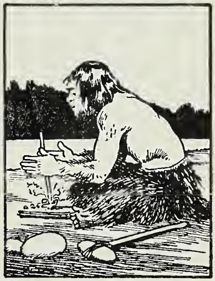
1. The environment is everything that surrounds us.
2. The factors of the environment are: water, air, light, heat, food, and the substratum which we live on.
3. Living things are sensitive to the factors of the environment and react favorably or unfavorably to these factors.
4. All living things use oxygen.
5. Light attracts some living things; others are repelled by it.

6. There is a range of temperature within which each living thing is best fitted to live.
7. All living things need water.
8. All living things need food.

These and other generalizations you will use when you study this unit, using them as foundations to build upon in the problems that follow.

PROBLEM I. TO WHAT EXTENT IS MAN A CREATURE OF HIS ENVIRONMENT?

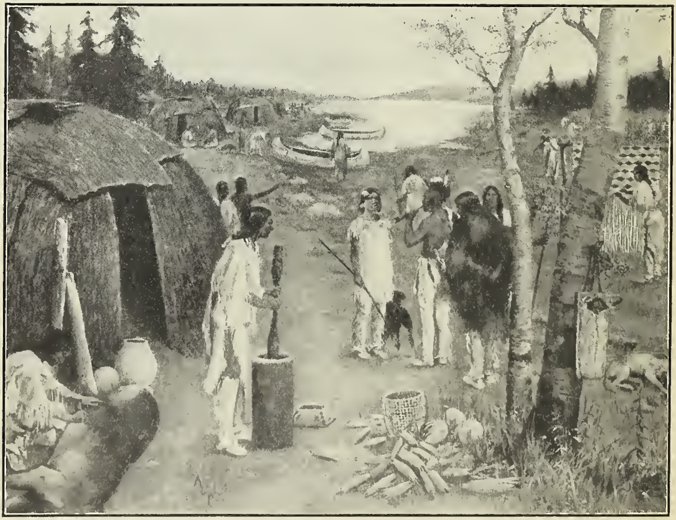
The Earliest Men. We do not know how many hundreds of thousands of years man inhabited this earth before we have any records of him. A few skulls and bones and rude stone implements tell us of man on the earth a good many thousands of years before the birth of Christ. These early men were probably broad-shouldered, big-chested creatures, with bodies covered with long hair. They slouched over as they walked because their legs were not straight. They probably lived in caves and subsisted on what food happened to be near. The earliest men probably did not use fire, except perhaps for protection and warmth. We can only guess when primitive savages began to cook their meat, and this was a big advance. They lived literally by the strength of their arm, for they had no weapons at first. We can imagine how some man, a little wiser than another, sharpened a long stick in the fire and made the first spear. Then perhaps another discovered that a sharp stone would bring down his prey. He fastened it to a stick, thus forming the first ax.


This method of fire-making has been used thousands of years. Do you know what made the sticks burn?

It is indeed a far cry from the cave man, living by the strength of his arm and spear, to the civilized man of today. We have progressed greatly, and the civilized earth is a much better place for habitation than it was in the days when man wandered about without a fixed abode. It is also a much safer place than it was in the days of Greece and Rome in spite of all their vaunted civilization. What has brought about this great change?

How Man Learns. One of the ways in which men and lower animals differ is that while animals can learn from experience, they cannot teach others, as men can. For example, a little chick just out of the shell picks a bad-tasting worm and gets an impression that lasts through life. It will probably never pick up such a worm again, but all other chicks will have to learn this same thing for themselves. On the other hand, man learns not only to profit by experience, but he can also *teach others what he has learned,* and thus hand down some of his knowledge to the next generation.

How Man Progresses. The making of fire was such an important process to primitive people that it was considered in the relation of a religious rite or ceremony, and by such means it was impressed upon the youths of the tribe. The boys of the tribe learned from their fathers how to make spears and bows and arrows for hunting and for warfare, and nets with which to catch fish.



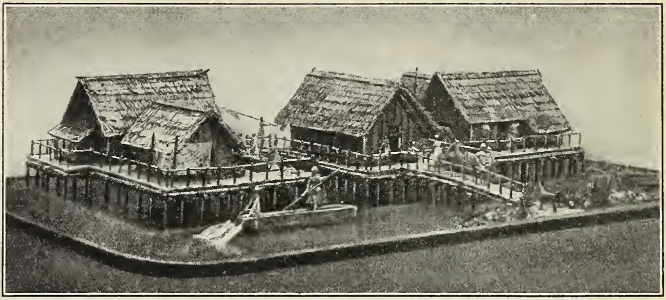
American Museum of Natural History

Show all the ways in which these Indians conquered or controlled their environment. Would you consider them a very primitive people?

The women doubtless did all of the household work. They probably first used wild rice or other cereals, perhaps later planting seeds and tilling their small fields in order to keep from starving when the hunting and fishing gave no return. Necessity doubtless prompted them to make vessels of soapstone or other soft stone in which they could cook. They learned to use fibers and weave them into rude clothes when skins were not obtainable. They taught their children the same things that they had learned to do.

Why Man Conquered His Environment. Thus we see that man in his early days was little better off than the bears and wild cattle that he fought with and ate after he killed them. He was as much influenced by his environment as were the other animals which competed with him. But as his superior intelligence began to be used, he soon outdistanced the other animals. He learned to use fire and thus kept warm and scared away beasts which might prey upon him. He drove these beasts out of their dens, warmed these caves with fire, and thus had a real shelter. He used the skins of the beasts he killed to sleep upon and to cover himself when cold. Man learned new things and was able to teach these things to his children. In this way man came to conquer his environment and not to be ruled by it as were the other animals.

The Domestication of Plants and Animals. It was a long step toward civilization when primitive peoples began to plant wild grasses and grains; for this gave them permanent abiding places and stores of food to subsist on when the hunting was poor. Wheat, for example, was cultivated in Europe probably as far back as the Stone Age, by people who knew only enough to make instruments of stone. Rice and wheat were cultivated by the Chinese centuries before Solomon reigned in Jerusalem. And the potato, which probably existed in a wild form in Chile, was used for food there long ages before the Spaniards came to America. Dogs, horses, and cattle were all tamed and domesticated by man many years before the dawn of civilization. Evidences have been found in the ruins of the lake dwellings in Switzerland, where a civilized people lived from 10,000 to 3000 years before Christ, that these people apparently had domesticated sheep dogs as well as watch dogs. They also had sheep, long-horned cattle, and swine, all of which must have been domesticated from the original wild



American Museum of Natural History

These lake dwellers had quite a high civilization several thousand years before Christ. Why do you think they built their homes in the lake?

forms living in this region. They also had cultivated apples, pears, grapes, as well as grains and flax. With the development of modern life, the improvement of plants and animals has kept steady pace, so that today we have many new forms grown every year.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

birds
horses
men
communication
millions
dogs
teach

nomad
environment
mountain
hundreds
beasts
grains
plains

water
like
conquered
learned
experience
cattle
killed

land
thousands
fruits
wild
domesticated
fire
billions

The earliest men were little better than (1)____ and lived (2)____ them. But with the discovery of (3)____ and due to the fact that man can (4)____ others what he has (5)____ by (6)____, man gradually gained dominance over his (7)____. As he (8)____ animals and plants he ceased to be a (9)____ and settled down. In the plant world he domesticated some (10)____ and (11)____, and in the animal world (12)____, horses, and (13)____. This took place (14)____ of years before the Christian era. But although man has (15)____ his environment, he still must live where there is (16)____, (17)____ which can be cultivated, and a means of (18)____ with others. Hence the (19)____ are more inhabited than the (20)____ regions.

PROBLEM TEST

Give an answer to the question and then match with it the best reason for your answer.

Primitive man was little better than the beasts with which he was in daily combat. How do you account for his place in nature today?

Answers

1. Man grew faster than the other animals he hunted.
2. Man was more active than the other creatures.
3. Man was more intelligent than the other living things.
4. Man has used up the food supply of the other animals.

Reasons

1. Man planted fields for himself, thus taking away food from the other wild animals.
2. Man can teach other men and thus accumulate knowledge which enables him to get the better of other less intelligent creatures.
3. Man could throw spears and run away quickly from the animals that preyed upon him.
4. He did not have as large families as did the other animals, so used less food and got along better.

PROBLEM II. HOW MAN HAS CHANGED HIS ENVIRONMENT

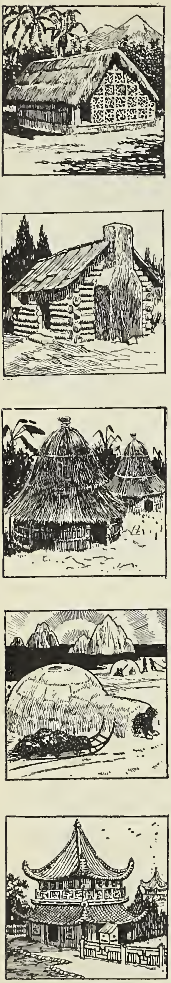
Changes in Man. We have seen that primitive man used his environment as he found it. For a good many thousands, perhaps hundreds of thousands of years, he lived pretty much as the other animals. But as he progressed through the ages, he learned new things about his environment and passed the knowledge on to his children. This inheritance of knowledge grew gradually with the ages until, like a snowball, it began to add to itself more rapidly. Today many more inventions and discoveries are made than we saw one hundred, fifty, or even twenty-five years ago. And what has caused these changes? The use of science and its laws.

Changes in Shelter. Probably the earliest men had no homes or perhaps had rude shelters in trees or in a cave. They used whatever was in the environment. Today we see this same use of the environment by many primitive peoples. Some use grass huts, built on a framework of sticks; nomads of central Asia use skins to cover their tents, for they have many sheep and goats.

The North American Indian covered his tepee with skins, and the Eskimo sometimes built a temporary igloo of snow blocks. Early settlers in this country built their homes and blockhouses of wood, while the peoples of Europe at the same period used largely stone. People used what was plentiful in their environment.

Early Temples and Tombs. But with the dawn of science and with man's interest in religion, we find temples and tombs built that were much finer than the homes. Look at the wonderful stone carved temples of the early civilization found in Mexico, Yucatan, and Egypt. The pyramids of Egypt particularly cause us to wonder how these great structures came to be constructed. They were built out on the desert far from the quarries where the stone came from that they are built of. Not only must these people have had scientific understanding of the use of rollers or wheels, but they must have built great inclined planes of earth in order to get the stones up to their final resting place.

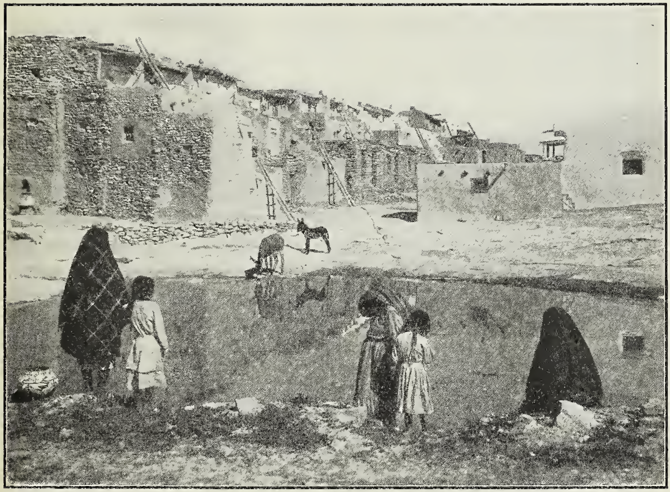
Shelters for Protection. Another stage of the building of shelters came with the grouping together of houses for mutual protection. Anyone who has seen the cliff dwellings at Mesa Verde, or the ancient pueblos of Acoma or Taos, can see the beginnings of our modern apartment house. But those primitive peace-loving Indians made their homes together for protection against wilder savages who destroyed their crops and killed their cattle. Or if you visit one of the interesting walled hill towns of Italy, you see again evidence of how people built together for mutual protection. All of the old feudal castles and walled towns were either built on hills or were almost surrounded by water.



In what countries do you think the above homes would be located?

Modern Buildings. What a change from the buildings of the past! Now steel and iron transported from some distant point are used to build skyscrapers, rising hundreds of feet into the air and capable of housing thousands of people. The walls of these buildings have much more window space than in the past and elaborate systems of heating, lighting, and transportation. What a change from the primitive dwelling of a few hundred years ago. No longer does man depend upon his immediate environment for his building materials; they come from all parts of the world.

Changes in the Use of Water. In earliest days, man had to be near a fresh water supply. In the west today many Indians carry their water, which they collect almost drop by drop, up long distances to their pueblos. It is said that Zuni Indians, taken to a great city and shown all the wonders of civilization there, were asked what they considered the greatest wonder of all. They at once replied: "Getting water from a faucet." It was not until men began to live in communities that they realized the need of



Atchison, Topeka & Santa Fe Railway

Acoma was built on the top of a high mesa. It depends on rain for its water supply and the drinking water is carried from a reservoir in an adjacent rocky mesa. Why did the Indians choose this site for their pueblo?

large amounts of water, and used it to carry off wastes. At the height of Rome's glory, she used 400,000,000 gallons of water a day, brought to her fountains and baths by 14 aqueducts. But even with all this wealth of water, very few homes had their own supply. Contrast this with the modern water supplies. If we add to this the other uses of water for power and transportation, we see how much we have advanced over our primitive ancestors.

Heating and Lighting. Again, what changes have taken place from the first fire of our primitive ancestors. Perhaps it was a chance burning log or an accidental spark that gave the first fire; then followed the evolution of the flint and steel as a means of starting a fire. The beginning of our modern heating plant may be seen in a fire built under the earth floor with ducts to carry the heat to the other rooms. Think of the greater use of fire since the early days. The smelting of ores, which is believed to date back to the time of the Egyptians, the use of heat in making pottery, and our modern utilizations of power from heat which has come with the discovery of coal and oil are indeed examples of our increased use of fire. And we may also trace the development of lighting from the time when a pine knot was the best light to be had at night, through the use of the tiny olive oil lamp of the Greeks and Romans, the later candle and oil lamp, the rather recent use of gas lamps, and the modern electric lights of all kinds.

Transportation. It is a far cry from the methods of transportation used by the primitive peoples to the carriers used in air, and on water and land today. When we see how slow and laborious transportation was before beasts of burden were domesticated, it is little wonder that man used the environment that surrounded him. How slow transportation was even in the days of our ancestors in this country! It took weeks to travel the same distance by oxcart that it takes hours to do today. Primitive man made a great advance when he used the rolling motion of the wheel instead of the sliding motion because rolling overcomes friction much easier than sliding. But what would he have thought of the use of rails; and more wonderful still, the use of the air? Again in the development of transportation our most rapid strides have been very recent, both because of the applications of science in new machines and because of the modern usage of fuels and electricity.

Communication. What a change there has been from the time when man did all of his communication by means of grunts, gestures, and nods of the head! We do not know when the first writing was done, but we do find that primitive peoples expressed themselves by means of pictographs, or simple pictures, which later became symbols and later still characters or letters. We may still find pictographs in places in the west, where the early Indians made them, while the monuments of Egypt, China, Central and South America show examples of symbols. Even today the Chinese use symbol writing. Our own alphabet probably originated with the Phoenicians over 3000 years ago, but it has been modified very much since that time. Civilization advanced more rapidly when people had means of communication with each other. But how much faster it has advanced since science took a part in communication. Compare the light signals of the Romans and the smoke signals of the Indians with the telegraph, telephone, or radio of today. Here again we find science has made tremendous strides in recent time, due to the accumulated knowledge which man has handed down from generation to generation.

U. S. Dept. of Agric.

The picture and symbol writing of the Egyptians. Do you know where our alphabet originated?

What Has Changed Modern Life the Most? This is a question that is hard to answer. When we look at such inventions as the sewing machine, the cotton gin, telegraph and telephone, submarine and airplane, the electric light and the radio, it seems as if some of these inventions might be given the credit. But when we realize that man's span of life has almost doubled since the dawn of civilization and when we think of the triumphs of modern sanitation, hygiene, and preventive medicine, we must realize that here is the field that has done most for man. Think of the primitive witch doctor or medicine man or of the astrologer and the magician, fakers all, and compare them with the scientifically trained doctors, nurses, and experimental workers in modern medicine, many of whom have given their lives in an attempt to solve some problem of disease in which it was necessary to use a human being for the experiment. Man's future is bound up in his ability to conquer disease and make a stronger and healthier as well as a wiser race on the earth. With the sacrifices of the modern experimental scientist, his future promises to be bright.

SELF-TESTING EXERCISES

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

recent
inventions
beasts
future
sanitation
communication
older
transportation
physicians
environment
trebled
doubled
immediate
sayings
science
laws
man
experimental
medicine
recently

Great changes have taken place in (1)____ as well as in his use of the (2)____ since earliest times. At first he could use only his (3)____ environment, but as he added to his knowledge and found new ways of (4)____ and (5)____, he began to extend his dominion over his (6)____ through his use of the (7)____ of science. Although tremendous strides have been made (8)____ in all branches of (9)____, none is more important than the work done in modern (10)____ and (11)____. Man's life span has been almost (12)____ in the past 1000 years and most of the gain has come through (13)____ discoveries by (14)____ and workers in (15)____ medicine.

NOTE. 4 and 5, 10 and 11 are interchangeable.

PROBLEM TEST

Select the best answer to the following question from the answers given below and then match with this the best reason for that answer.

Man of all the inhabitants of the earth has been able constantly to improve his environment and better his own condition because

Answers

1. He lives longer than other animals.
2. He sees and hears better than other animals.
3. He is more active than other animals.

4. He can teach his offspring and thus hand down some of his knowledge.
5. He is a higher animal.

Reasons

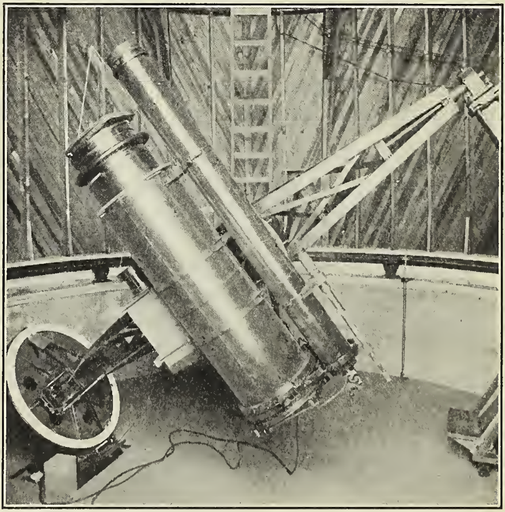
1. Although many animals are more active than man, he is able to catch them by means of his inventions.
2. Although birds probably see better than man and many animals hear better, nevertheless man's senses are very keen.
3. Higher animals are upright, have large brains, and are more intelligent than lower animals.
4. Man can hand down what he has learned to his offspring and they in turn hand it down to their children. This constitutes our social inheritance and is the basis of all our progress.
5. Man does not live as long as the elephant and a few other animals, but he has a much longer life span than do the monkeys and other intelligent animals.

PROBLEM III. HOW HAS MAN USED THE SCIENTIFIC METHOD IN CONQUERING HIS ENVIRONMENT?

How the Scientist Works. We have seen from our previous study that scientists go to work in a very definite way. First they have a problem they want to solve, then they try to find ways of solving the problem. They devise experiments, gather facts, and piece them together so as to reach some sort of a conclusion. But they always test out the conclusion many times before they can say, "This is a law or a scientific principle." They remain open-minded, and if new facts are discovered that change the conclusion, they accept the facts and make a new conclusion that is in accord with the facts.

How Neptune Was Discovered. This working out of the method of science is seen in the discovery of the new planets, Neptune and Pluto. Many years ago the English philosopher, Sir Isaac Newton, discovered the law of gravitation. This law has been for years applied in our knowledge of the workings of the solar system. We know that the sun, because of its great mass, holds the planets in their orbits about it, and that these orbits are regular. About the year 1846, two mathematicians, one in England and another in France, pointed out the fact that the planet Uranus moved irregularly in its orbit. They showed that this irregularity might be caused by the pull of another planet farther out in space. The Frenchman actually computed the course of this then unknown planet and wrote to an astronomer friend of his to point his telescope at a certain place in the heavens at a certain time to see if it was a new planet that caused Uranus to act as it did. The astronomer did so and there was a planet just where the French mathematician had said it would be. This planet was later named Neptune.

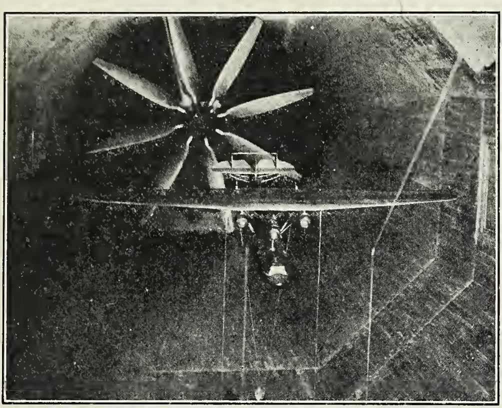
How Pluto Was Discovered. Recently this wonderful use of scientific facts was repeated in the discovery of the planet Pluto, a little mass about the size of our moon, which is so far away from the sun that its orbit is enormous. It takes 250 years for it to make a complete revolution around the sun. Dr. Percival Lowell, director of the Lowell Observatory at Flagstaff, Arizona, in 1915 proved mathematically the existence of this planet from slight deviations of the planet Neptune in its orbit, just as Leverrier had



Lowell Observatory

The Lowell Observatory at Flagstaff, Arizona, and the telescope through which the new planet Pluto was discovered.

previously done in the case of Uranus. Dr. Lowell actually photographed the new planet, but because the methods used at that time were not as good as those at present, the planet was not found on the photographic plates. However, by constant research and through use of the mathematical formulas computed by Dr. Lowell, the planet was finally found in 1930.



Guggenheim Laboratories, School of Engineering, New York University

A wind tunnel and model airplane. Read your text to see how these are used.

Finding Facts by Research. Let us take another more practical kind of work done by the scientist. Let us suppose we visit a testing laboratory of an airplane factory. One problem in building airplanes is to find out how much wind pressure the wings will stand. To find this out, a wind tunnel is made in which the velocity of the wind can be measured accurately as it is produced by a fan. A model airplane is balanced in the tunnel and as the wind velocity is increased, one worker balances with weights the wind forces on the model plane, finding just what weights will hold it in place in a given velocity of wind. At the same time, another worker is measuring with delicate instruments the exact speed of the wind in the tunnel. From the data obtained by these two workers and the use of mathematical laws which relate to velocity, it is possible for these men to determine exactly the action of a full-sized airplane under air velocities many times as great. The laws of science hold in one case as they do in the other. And the wing can thus be constructed to withstand the greatest pressure that it is likely to meet when traveling through the air as a part of a full-sized plane.

Science and Propaganda. These interesting examples show us one thing very clearly. The scientist must often work for a long time just gathering facts before he is able to come to a conclusion worth anything. David Starr Jordan once said, "There was never a time when men knew more than in the 13th century, but practically everything they knew was wrong." History repeats itself today. Never has there been a time when people were so much led about by propaganda and half truths. We are asked to draw conclusions based on half truths or on actual falsehoods cooked up under the name of statistics. Many advertisements base their claims on this sort of thing. We do not seek evidence, based on proved facts, but are willing to believe what people *say* rather than take time to *find out* the *facts* for ourselves.

What Are Some of the Attitudes of the Scientist? The lesson that science ought to teach us is that we must get our facts first and then draw our conclusions. If our facts are sound, then our conclusions will be sound. But if our evidence is based on untruths or half truths, then our conclusions will not tell us the truth. Here is where the laboratory and the observations of the scientist count, for the experiment is a question asked of nature and nature always tells the truth. The scientist knows that nothing can happen without a cause and tries to find the cause by experiment, observation, and, above all, by collecting facts and weighing them before he makes up his mind as to the conclusion to be drawn from the facts. The scientist after collecting his facts tests them to see if they are sound; if they can be relied on then uses them as evidence. The scientist demands *evidence,* or facts that furnish proof, and uses only evidence to arrive at his conclusions.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

two
evidence
belief
one
propaganda
suns
open-minded
thinking
nature
conclusion
Neptune
three
half
moons
verification
discovered
truth
invented
observation
planets
Pluto
four
expected
based

It quite often happens that new facts are (1)____ which show that a former (2)____ can no longer be held. It is best always to be (3)____ and ready to draw a new (4)____. Careful (5)____ and clear (6)____ led to the eventual discovery of (7)____ new (8)____, Neptune and (9)____. Conclusions must always be (10)____ upon the best (11)____ available. If we base our conclusions on (12)____ truths or (13)____, we cannot be sure of the results. Remember that an experiment asks a question of (14)____ and (15)____ always tells the (16)____.

PROBLEM TEST

Select from the following list the answer that you think is best and then match this answer with a reason that you believe is valid.

John was invited out to dinner the other evening and found he was to be the 13th person to sit down at the table. What should he do?

Answers

1. He should sit down and make no comment.
2. He should refuse to sit down.
3. He should pretend to be ill and go home in order to save his hostess embarrassment.

Reasons

1. There is a superstition that some one of the group will die before the year is out.
2. There is no scientific evidence that sitting down 13 at a table will hasten anyone's death.
3. If a death among the group does take place, it is chance, not due to the superstition.
4. A lie is better than a social error.
5. There are many authentic cases of death within a year when 13 people sit down at a table.
6. A person there might overeat or choke himself to death.

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. These big ideas we call generalizations. The following are some that we can form as a result of our reading and thinking about the unit.

1. Primitive man was little different from the other animals.
2. Primitive man utilized his environment but did not go beyond it.
3. There has been a change or evolution in man's method of life.
4. These changes have been very slow.
5. Man has been able to improve and conquer his environment because he can teach his offspring and they in turn teach their children.
6. Man has used the scientific method in conquering his environment.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers* × $2\frac{1}{2}$.

I. **Primitive man:** (1) was no more intelligent than the other beasts; (2) lived in security; (3) cultivated the land; (4) was a hunter; (5) was probably broad shouldered but not erect.

II. **Man differed from the lower animals:** (6) because he had no hair on his body; (7) because he could make weapons with which to kill them; (8) because he can learn from experience; (9) because he can teach others of his kind what he has learned; (10) because he eats cereals.

III. **Primitive man learned to domesticate:** (11) wild rice; (12) potatoes; (13) wolves; (14) grasses; (15) fishes.

IV. **Man's earliest shelters were:** (16) apartment houses; (17) nothing; (18) caves; (19) whatever he could get in his environment; (20) trees.

V. **The earliest methods of communication were probably by means of:** (21) writing; (22) pictographs; (23) signals; (24) wireless; (25) rude telephones.

VI. **The earliest method of transportation was:** (26) flying; (27) walking; (28) by pack animals; (29) motor cars; (30) rude wagons.

VII. **The method of science:** (31) means that a person who uses it must always have an end in view, a problem to solve; (32) can be used to solve many of our problems in daily life; (33) uses experiments; (34) uses propaganda; (35) uses unproved statements made by reliable people.

VIII. **The scientist uses:** (36) accurate tools for the measurement of data; (37) speculation; (38) theory; (39) the proved work of others; (40) evidence based on facts.

PRACTICAL PROBLEMS

1. Can you give an example of where chance has led to an important scientific discovery?
2. Your classmate John is always " cocksure " of everything he does and says. Can you prove to him that he is not using the scientific method in his thinking?
3. You read of the present century being "the age of science." What evidence can you bring forward to prove this?
4. Make a list of all the achievements you can and classify them under the headings of physical, chemical, biological, astronomical, medical.
5. What recent experiences have you had or observations have you made that lead you to believe the force of gravity is still active?
6. Think of some practical problem in whose solution you have a personal interest. Map out a course of procedure you might follow in an attempt to solve it.
7. List ten ways in which you think man is conquering his environment.

INTERESTING THINGS TO READ ABOUT

1. How Newton discovered the law of gravitation.
2. How Galileo made his first telescope and what he found with it.
3. How Harvey and other early scientists worked independently on the blood and made researches that resulted in our present idea of blood circulation.
4. How Morse invented the telegraph.
5. How Whitney invented the cotton gin and what resulted from this discovery.
6. What Beebe found by means of the bathosphere.

LEISURE TIME ACTIVITIES

1. Find out as many examples as you can of " good and bad luck " and see how many cases you can explain from a scientific viewpoint. Try for some of the following books in your school or community library and see how many examples of the scientific method you can find in them.

Beebe, *Half Mile Down.* Putnam.
Chant, *Our Wonderful Universe.* World Book Co.
Fontany, *Other Worlds Than This.* Wilcox and Follett.
Washburne and Reed, *The Story of Earth and Sky.* Century.

2. See how many examples of open-mindedness you can find in your own attitudes toward everyday problems.

3. How many of the attitudes of the scientist do you use in your everyday thinking?

4. Pursued by Bad Fortune

Special Cable to THE NEW YORK TIMES.

London, Oct. 22, 1934 — Flying Officer Gilman and J. Y. C. Baines were thirteenth in the race to Melbourne when they were killed in their crash in Italy today. They had been dogged by ill luck throughout.

Comment on the above clipping, from the standpoint of scientific thinking in view of the second excerpt from the same article.

Both were amateur sportsmen and entered privately in the speed and handicap events, flying a day bomber purchased from the Air Ministry's old stock.

SCIENCE CLUB ACTIVITIES

1. Plan a meeting at which every member will give an actual example of scientific attitudes shown by some other member in his daily life in the school.

2. Or plan a meeting at which each member of the club will try to find an example of attitudes shown which are not scientific. It will be more fun if you can take such examples from your own group.

3. Arrange a debate on the subject: Resolved: That our life actions should be ruled by science rather than by the emotions.

4. Have an exhibit made for the bulletin board to show examples of how great scientists have made worth-while discoveries.

REFERENCE READING

Beery, P. G., *Stuff.* Appleton, 1930.
Chant, C. A., *Our Wonderful Universe.* World Book Co., 1929.
Fontany, E., *Other Worlds Than This.* Wilcox and Follett, 1930.
Holland, Levy, Huxley, etc., *Science in the Changing World.* Century, 1933. (Ed. Adams, M.)
Washburne, H., and Reed, F., *The Story of Earth and Sky.* Appleton-Century, 1933.

Survey Questions

In what ways are we dependent upon the air?

How does man use compressed air?

What important factors determine weather?

How are the weather predictions in the papers made?

Do you understand how clouds are formed?

What kinds of storms are most destructive?

What is the difference between weather and climate?

Galloway

UNIT III

HOW THE AIR INFLUENCES MAN'S ACTIVITIES

PREVIEW

Anyone who has flown a kite realizes that moving air has force. Perhaps some of you have seen one of the picturesque old windmills that used to be common down on Cape Cod, or you may have been on a farm in the West where a windmill is in actual operation. Or perhaps you have sailed a boat and know how to make use of the force of the air in tacking or sailing before the wind. More likely you have lived in a great city and have heard the rat-tat-tat of the pneumatic drills on buildings in the course of construction. Here is another use of air — air under compression. These are only a few of the hundreds of ways air is used in modern life.

We sometimes forget that we live surrounded by moving air, and that dry air or moist air, cold air or warm air, still air or moving air give us our weather and climate.

Are you affected in any way by the weather? Some of us are affected more than others, but there is no doubt that weather plays a considerable part in our daily lives. Not only are our picnic, skating, and coasting parties determined by the weather, but our outlook on life is usually influenced by the kind of day it is. A cold clear day with low humidity makes us feel "peppy"; we are ready for work or play. A dull, warm day with high humidity influences many of us to the extent of making us "blue" or depressed, and, in any case, we are uncomfortable. We feel hot and "sticky" and we become dull or irritable. But although weather is important to us individually, climate is even more important. Think of the differences in climate in this great country of ours and the different occupations which depend upon climate. Have you experienced a winter on the coast of New England with its easterly gales, heavy snows, and fogs; or one on the plains of the Dakotas or Wyoming with blizzards sweeping down from the Arctic north; or one in almost the same latitude, the mild but rainy winters on the Pacific coast in the state of Washington? Compare the bright sunshiny days of southern California with the moist warmth of Florida, or the heat of Death Valley and the Arizona desert with the delightful climate of the southern California coast not many miles away. Think of the differences in rainfall between the eastern and western edges of the Sierra Nevada Mountains at the latitude of San Francisco. Compare the humid atmosphere of a summer in the Mississippi Valley with the cool and bracing summer in the Rocky Mountains, in the same latitude, but at an elevation of from 6000 to 8000 feet higher. The differences in climate have played a tremendous part in the progress of man, for civilization seems to advance more rapidly in certain kinds of climate.

We are told that the first Pilgrim settlers were much disappointed at the severity of the New England climate. Although it was fully 100 miles south of the latitude of England, the winters were much more severe and the summers much hotter. The conditions were even more extreme in other parts of the United States that lie farther inland on the same parallel of latitude. The early settlers did not realize that England and the whole coast of northern Europe owed its mild climate to the westerly winds blowing from the warmer ocean.

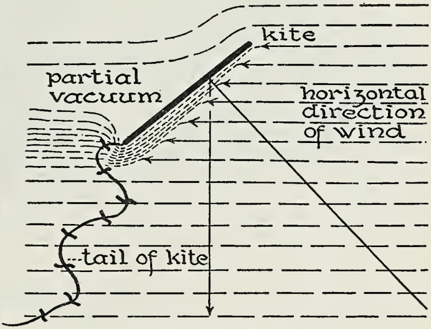
Before beginning the study of this unit, try to recall the principles and generalizations relating to this factor of the environment that you have already learned. Some of these are the following:

1. Air has weight and exerts pressure.
2. Air can be confined and its pressure increased.
3. Moisture exists in the air in varying amounts.
4. Heat causes evaporation of water. Removal of heat from water vapor causes condensation.

PROBLEM I. WHAT WORK IS DONE BY MOVING AIR?

We have seen that air in motion possesses great force. Think of the storm that dashes vessels on rocks or tears down buildings. We speak of moving air as wind, and we say that winds are caused by variations in air pressure. We have also seen that air pressure varies greatly in different parts of the country at a given moment, so we may be sure that air is always in motion. In some parts of the earth this movement is much more constant than in others; as, for example, in the tropics we have the trade winds, and on the western plains the prevailing westerlies blow quite constantly.

How We Fly Kites. Almost everyone has tried to fly a kite. They are not always flown for fun; witness Franklin's kite by means of which he made his discoveries on electricity. The Weather Bureau often sends up box kites to obtain wind and temperature records. Photographs are made from similar kites, and occasionally such kites are used to carry lines over rivers or gorges by means of which cables will later be strung. If we ask what holds a kite up, we may look at the accompanying diagram. We see that air presses on the under surface of the kite, and as the string holds it back, the air becomes somewhat compressed on one side, while on the opposite side a partial vacuum is formed. Since the air pressure just above the kite is lowered, the increased pressure from below forces the kite up against the pull of gravity. The same forces lift the wings of the airplane in a similar manner.



Explain why a kite will fly.

How Windmills Do Their Work. We have seen that some parts of the world are supplied with nearly constant winds. As one sails by the island of Barbados in the West Indies, he sees hundreds of little windmills working away for all they are worth in the trade wind, while in Holland, old-type mills with four great sails are numerous. As we go out on the Western Plains where the winds blow quite constantly from 5 to 18 or more miles an hour, we find many windmills which are used for pumping water, operating churns, cream separators, and feed cutters on the farms. The

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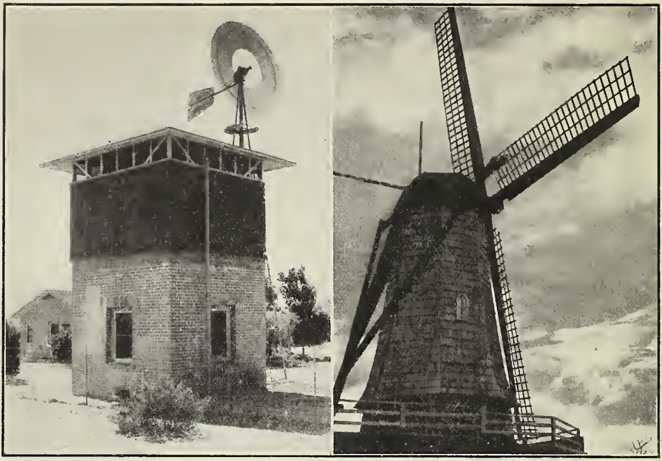


Wright Pierce *L. J. Heflerman, R. I. Nesmith and Associates*

Compare the modern windmill at the left with the old-fashioned windmill from Cape Cod. Which do you think the more efficient? Why?

modern windmill has a wheel with inclined blades arranged so that the moving air strikes against them and causes them to rotate. A vane sticking out behind regulates the movable wheel so that it always faces the wind. These windmills utilize up to 12 per cent of the wind's energy. The screw propeller of the boat and the electric fan reverse the process of the windmill. Can you explain how this is done? Man has made use of the wind to sail boats for a long, long time, but it was only in comparatively recent years that he discovered how to tack, or to make a boat go against the wind, by putting the sail at an angle to the wind and turning the rudder so that the boat would head up into the wind. This discovery was made in 1537 by an Englishman named Fletcher. It is said that this discovery was made use of by the English fleet when the great Spanish Armada sailed out to conquer England. The English boats were smaller and could move against the wind, while the Spanish galleons were huge affairs only capable of sailing with the wind. Consequently the English had the Spanish at a great disadvantage and defeated them. Sailing vessels not so long ago were very important in this country, and the old clipper ships that sailed out from Salem used to make as much as 400 miles in a single day. Airplanes travel, of course, much faster with the wind than against it, and wind plays a very important part in long-distance flights over the ocean.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

force
power
compression
vacuum
pressure
airplanes
tacking
below
wings
variation
sail
movement
wind
windmills
rudder
sailing

Moving air results from (1)____ in air (2)____. In places where the winds are constant, (3)____ are used for (4)____. By means of (5)____ a sailboat can make progress against moving air currents. To do this requires skillful use of (6)____ and (7)____. Kites rise because when held at an angle to the (8)____ increased pressure is produced (9)____ and a partial (10)____ above the kite.

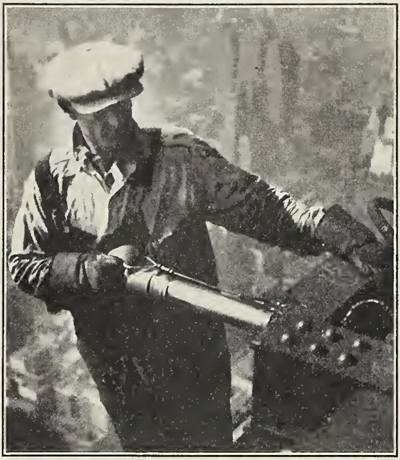
PROBLEM TEST

In constructing a telephone line, it is found necessary to cross a deep canyon 250 yards from one cliff to the opposite cliff. There is no crossing place nearer than one mile away.

Suggest different ways by which the line may be carried across. Which of the different possibilities would you choose? Give reasons for your choice.

PROBLEM II. HOW DOES COMPRESSED AIR WORK FOR US?

We all know that the free air at a filling station is compressed by a pump and held in the tank under pressure. When the tire of our car is connected with the tank, air flows into the tire and is shut off when we get the required pressure. If we close the outlet of an air pump and push the piston three fourths of the way down, air, which is elastic, is crowded into one fourth of the space it originally occupied and the pressure is four times as great. This elasticity is used in many kinds of work. Because the energy used to compress the air remains stored in it until it expands to its original volume, compressed air is used for many purposes. It can be let through pipes easily and used to do work at a distance from the compressor.



R. I. Nesmith and Associates

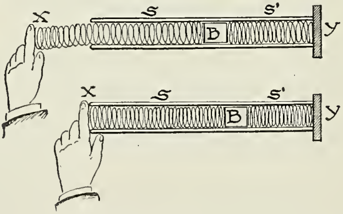
What is this man doing? Notice the height at which he is working.

Work Done by Compressed Air. Compressed air runs drills which are now used everywhere for breaking up old pavements, drilling holes in rock, and particularly in heading rivets which hold steel girders together. It is used in sand-blasting machines by means of which rock, concrete, and stone buildings are cleaned. It is used in operating sprayers for destroying insects and for spraying paint. Other important uses of compressed air are found in the plumber's torch and the blacksmith's bellows.

Demonstration 1. How Atmospheric Pressure Moves Bodies.

a. Elastic steel springs

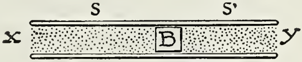
Compress two springs S and S' so that they hold a cork B in place inside a glass tube. B is held stationary by the equal opposite forces of S and S'. Release Y slowly. This allows spring S' to have more



room and the coils to spread farther apart or expand. It pushes with less force against B. What happens to B?

b. Elastic spring of air

In a similar way study the spring of the air. Use a glass tube to hold the air and the cork B which moves easily in the tube. The particles of air are crowded together just as much at S as they are at S'. The air is like coiled springs pressing equally against opposite sides of B. Suck air at Y from the space S'. The air left there will then expand and there will be fewer particles left to push against B. What happens to B? Was it pushed? Was it pulled? Explain.



Uses of Air Pressure. Nearly all the practical uses of the air involve the removal of pressure of the air from one portion of a body while the air continues to press upon the other parts, so that there are unequal forces of pressure acting upon the body; thus motion is caused. The vacuum cleaner, the bulb atomizer, and other devices make use of this principle. (See Unit III, *My Own Science Problems.*)

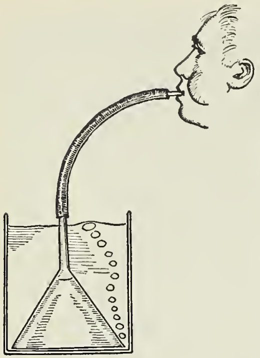
The Air Brake. In the case of the air brake, a pump on the engine compresses the air in a reservoir connected to the brake cylinder by means of a pipe. When the engineer puts on the brakes, he moves a valve which causes air from the storage reservoir to enter a small reservoir next to the piston. Here air exerts a sufficient force to move the brake shoes against the wheels of the car. When the engineer wishes to cut off the air from the brakes, a coil spring in the brake cylinder pushes the piston back to its original position, and the brake shoes are released from the wheels. Air brakes are used on steam trains, electric cars, busses, and trucks.

Pneumatic Delivery System. Money or mail may be carried in cylinders which move through tubes to different parts of a building, or beneath the city streets from one building to another. These cylinders may be moved by compressed air or in a vacuum system, by atmospheric pressure.

Demonstration 2. How Man Can Work below the Surface of the Water.

a. Push an inverted glass down into a jar of water. Does the water fill the glass?

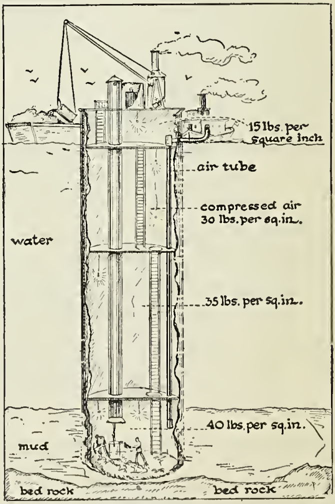
b. Attach a rubber tube to the end of a funnel. Thrust the funnel mouth down into the water. Does water enter the funnel?



c. Blow through the rubber tube. What changes occur when you blow air into the funnel?

Explanation. What is the reason for the result in *a*? Why was the result in *b* different from that in *a*? Why was the water driven out of the funnel in *c*? How is the air pressure in the funnel affected in *c*?

Compressed Air Used under Water. The above experiment shows how a diving bell or a caisson is used. In making tunnels which pass through soft mud under rivers, or in laying foundations for bridges or great buildings, it often becomes necessary to use compressed air. Great bottomless metal cases, called caissons, are driven into the mud, and air is pumped into them. The pressure of the air in the caisson prevents water and mud from entering, and workmen are able to take the mud and sand out from the front, or bottom of the caisson, and pass it up to the surface through air locks. The caisson is pushed forward by hydraulic jacks, or it may sink into the mud because of its own weight, causing deeper penetration. A study of the diagram shows that although air pressure at the surface will be 15 pounds to the square inch, men may work inside the air lock at a pressure of 40 or more pounds to the square inch. In order to be-



Explain after reading the text why the caisson is used for work in soft mud under water.

come accustomed to this great extra pressure, the workmen must change from the outside to the inside very slowly. They are unable to work for more than two hours at a time without exhaustion.

Caisson workers are often troubled by a disease called the "bends," which is caused by nitrogen being forced under pressure into the blood vessels, where it forms tiny bubbles. These bubbles cause intense pain in the muscles and joints. Years ago this disease, along with other injuries, took a high toll in deaths of people working under water, but in recent years the difficulty has been largely overcome, through an understanding of how to treat it and especially how to prevent it. It is prevented by getting the body accustomed to the change in pressure more slowly than formerly.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below, and arrange them in proper numerical order. The same word may be used more than once.

compressed
water
atmosphere
light
gas
pressure
expand
contract
air
weight
elastic
caissons
forced
volume
work
irregular
allowed
loads
atmospheric
reduced

Air is like a spring because it is an (1)____ body. It can be (2)____ into a small space, but when (3)____ to (4)____, will increase in (5)____ indefinitely. Air under high (6)____ sustains heavy (7)____, and does a variety of kinds of (8)____. Men can work below the surface of water in (9)____ because of the (10)____ (11)____ used there. The atomizer and carpet sweeper make use of (12)____ (13)____, but the automobile tire and automobile lift make use of (14)____ (15)____.

PROBLEM TEST

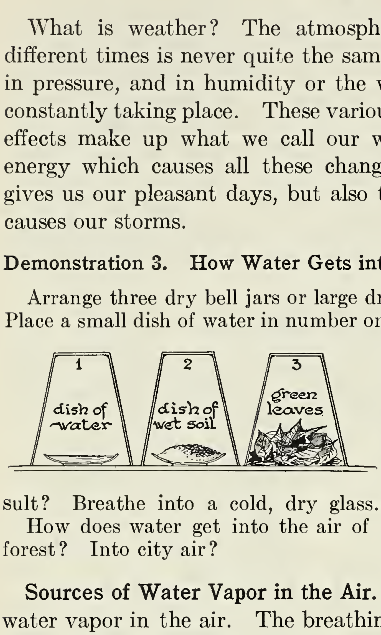
1. Compressed air will run an engine just as compressed steam will. How do you think it would work to use air from the tank to run an engine which drives the pump that compresses the air in the tank? Explain.
2. Which can be made to give the greater pressure, the atmosphere or compressed air? Explain.
3. How might it be possible to run an engine without coal and water?

PROBLEM III. WHAT PART DOES MOISTURE PLAY IN OUR WEATHER?

What is weather? The atmosphere which surrounds us at different times is never quite the same. Changes in temperature, in pressure, and in humidity or the water content of the air are constantly taking place. These various changes and their resulting effects make up what we call our weather. The source of the energy which causes all these changes is the sun. It not only gives us our pleasant days, but also through its release of energy causes our storms.

Demonstration 3. How Water Gets into the Air.

Arrange three dry bell jars or large drinking glasses in the sunlight. Place a small dish of water in number one, a dish of wet soil in number two, and a large handful of green leaves in number three. After a period of two or three hours, remove the jars from the sunlight and allow them to cool rapidly. What is the result? Breathe into a cold, dry glass. Result?



How does water get into the air of a room? Into the air of the forest? Into city air?

Sources of Water Vapor in the Air. There are many sources of water vapor in the air. The breathing of animals, the burning of fuels, and the decay of plants and animals, all give water to the air, but by far the largest sources are bodies of water, the moist earth, and growing vegetation. This water vapor is in the form of an invisible gas which we cannot see until it separates out as clouds, dew, fog, or mist.

Demonstration 4. Saturated Air.

Place 10 c.c. of water in a shallow dish in the open air. Place a second portion of 10 c.c. of water in a similar dish and cover with a bell jar. Which liquid disappears first? Why?

Saturated Air. The above demonstration indicates that a confined body of air is limited in its capacity to hold moisture. The air of the room easily took up all of the water in the unconfined dish, but the air in the bell jar, being much less in amount, could not take up all of the water. Heat is required for the evaporation of water and, in general, the greater the amount of heat, the more rapid is the evaporation. It is, therefore, true that the warmer the air the greater will be its capacity to hold moisture. For example, air at 90° F. can take up more water than air at 70° F. Air holding all the moisture it can take up is called *saturated* air. When the moist air in the room comes in contact with the window on a cold day in winter, it may be cooled below the saturation point, or *dew point*, and then the excess water separates out, coating the glass with fine droplets of water.

Humidity. What do we mean by humidity? We have felt the effect of high humidity, because the discomfort of a muggy day in summer is caused by it. Air is seldom saturated with moisture. The weight of invisible water which a unit volume of air (a cubic foot) actually holds is called *absolute humidity*. The *relative humidity* is the ratio between the amount of water a unit volume of air actually holds and what it could hold if it was saturated.

Demonstration 5. How to Measure the Relative Humidity of the Air.

Wet the muslin covering of the bulb of a wet-bulb thermometer and whirl the thermometer rapidly in the air or fan a current of air upon it. Read the temperature. Record the lowest temperature reached. Also record reading of a dry-bulb thermometer. Refer to the table which follows and record the humidity of the air as indicated in the table for the readings noted.

The following table gives the relative humidity at different temperatures for given dry-bulb readings.

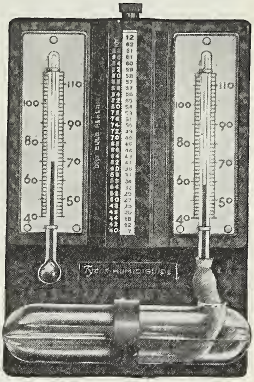
The humidity which we see reported in the daily papers is the relative humidity. When the humidity is 60 per cent, the air contains 60 per cent of the amount of water that it would contain at that temperature if the air were saturated. Let us suppose one cubic foot of air holds 5.46 grains of water vapor at 80° F. The air is capable of holding 10.92 grains of water vapor at 80° F. The relative humidity is $\frac{5.46}{10.92}$, or 50 per cent. The amount of water vapor in the air is measured by means of the wet- and dry-bulb thermometers, or the *hygrometer*. This instrument really consists of two thermometers, the bulb of one being kept moist by a wick

TABLE FOR FINDING RELATIVE HUMIDITY. PERCENTAGES

Dry Therm. (air temp.)	Difference between Dry- and Wet-bulb Thermometers														
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18
0	68	35	3												
2	71	41	12												
4	73	46	19												
6	75	50	25	1											
8	77	54	31	9											
10	79	57	36	15											
12	80	60	41	21	3										
14	82	63	45	27	10										
16	83	66	49	33	16	0									
18	84	68	53	38	22	7									
20	85	70	56	42	28	14									
22	86	72	59	45	32	19	7								
24	87	74	61	49	36	24	12	0							
26	88	75	64	52	40	29	18	7							
28	88	77	66	55	44	33	23	12	2						
30	89	78	68	57	47	37	27	17	8						
32	90	79	69	60	50	41	31	22	13	4					
34	90	81	72	62	53	44	35	27	18	9	1				
36	91	82	73	65	56	48	39	31	23	14	6				
38	91	83	75	67	59	51	43	35	27	19	12	4			
40	92	84	76	68	61	53	46	38	31	23	16	9			
42	92	85	77	70	62	55	48	41	34	28	21	14	0		
44	93	85	78	71	64	57	51	44	37	31	24	18	5		
46	93	86	79	72	65	59	53	46	40	34	28	22	10		
48	93	87	80	73	67	60	54	48	42	36	31	25	14	3	
50	93	87	81	74	68	62	56	50	44	39	33	28	17	7	
52	94	88	81	75	69	63	58	52	46	41	36	30	20	10	0
54	94	88	82	76	70	65	59	54	48	43	38	33	23	14	5
56	94	88	82	77	71	66	61	55	50	45	40	35	26	17	8
58	94	89	83	77	72	67	62	57	52	47	42	38	28	20	11
60	94	89	84	78	73	68	63	58	53	49	44	40	31	22	14
62	94	89	84	79	74	69	64	60	55	50	46	41	33	25	17
64	95	90	85	79	75	70	66	61	56	52	48	43	35	27	20
66	95	90	85	80	76	71	66	62	58	53	49	45	37	29	22
68	95	90	85	81	76	72	67	63	59	55	51	47	39	31	24
70	95	90	86	81	77	72	68	64	60	56	52	48	40	33	26
72	95	91	86	82	78	73	69	65	61	57	53	49	42	35	28
74	95	91	86	82	78	74	70	66	62	58	54	51	44	37	30
76	96	91	87	83	78	74	70	67	63	59	55	52	45	38	32
78	96	91	87	83	79	75	71	67	64	60	57	53	46	40	34
80	96	91	87	83	79	76	72	68	64	61	57	54	47	41	35
84	96	92	88	84	80	77	73	70	66	63	59	56	50	44	38
88	96	92	88	85	81	78	74	71	67	64	61	58	52	46	41
92	96	92	89	85	82	78	75	72	69	65	62	59	54	48	43
96	96	93	89	86	82	79	76	73	70	67	64	61	55	50	45
100	96	93	90	86	83	80	77	74	71	68	65	62	57	52	47

dipping into a vessel of water. The evaporation of water from the cloth around the wick cools the mercury, and the more rapid the rate of evaporation, the more rapidly the mercury will fall and the greater will be the difference between the two thermometer readings.

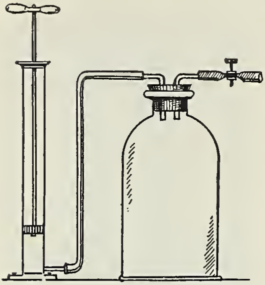
Importance of Humidity. Every one of us knows how uncomfortable a crowded hall becomes after we have been in it for a short time. The room seems suddenly hot, but, as a matter of fact, if we were to take the temperature, we would not find it very much higher. We would, however, find a very great rise in humidity, caused by the giving out of moisture from the breath and through the skins of the people in the room. The ventilation of public buildings is an important matter, and so is the ventilation of our schoolrooms. Heated rooms are sometimes made more comfortable by electric fans, which produce a circulation of air. In winter, higher humidity in the rooms of a house or factory is desirable, for with more moisture in the air, one can be comfortable at a lower temperature, and one is much less likely to take cold upon going outdoors. A relative humidity of 60 per cent to 70 per cent is desirable in the house. Humidity is important in many industries. In weaving cotton cloth, the threads break more easily in cold, dry air than in warm, moist air, hence a high humidity must be maintained artificially in the weaving rooms. On the other hand, the drying of clothes and the making of hay require a dry atmosphere.



Explain how this instrument works.

Demonstration 6. To Form a Cloud.

Place a little benzene or alcohol in a large strong flask (the larger the better). Close the flask with a rubber stopper having two holes. Place glass tubes in the holes as shown in the figure. Tie the stopper in securely. Close one glass tube with a rubber tube and clamp. Connect a compression air pump to the other glass tube. Now pump air slowly into the flask. Turn the flask to wet the surface with the liquid and wait a moment or two to allow the air to absorb all the vapor it can. Now place the glass flask in direct sunlight if possible. Observe what happens when the clamp is opened.

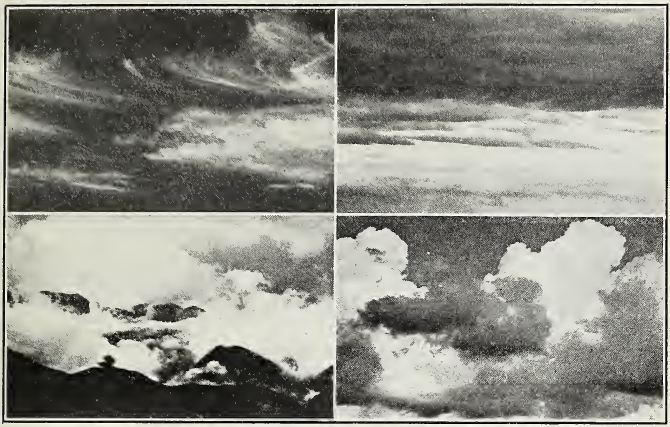


When the pressure is suddenly released, the air inside the flask expands so rapidly that a quick lowering in temperature results. This sudden drop of the temperature cools the air to the point where it is not able to hold so much vapor, which, therefore, condenses to form drops of liquid. If you are near the flask, you will be able to see tiny particles of mist that make up the cloud in the flask. If you close the clamp on the rubber tube and again pump air into the flask and increase the pressure, the air becomes warmer and the cloud disappears in an instant.

How Clouds and Rain Are Produced. Instead of alcohol or benzene, water may be used in the experiment just described, but the cloud formed will not be so dense. This experiment shows the principle upon which most of our clouds are formed. As air moves over the earth's surface and absorbs heat, it also increases its load of water vapor. The increased warmth makes the air lighter and causes it to rise.

As the moist warm air rises, it expands, and when it expands, it becomes cooler. Cooling reduces the capacity of the air to hold moisture. As a result, at some height, conditions are such that the moisture in the air is condensed into little drops of water, forming clouds. These minute particles of moisture may increase in size by further condensation upon them, or several particles brought into contact may unite, so that finally the particles are too heavy to remain suspended in the cloud and they fall as rain.

In the Far West the rain clouds coming from the coast lose much water in passing over the mountain ranges, so that the great plains east of the Rocky Mountains receive comparatively little rainfall. A study of the map on page 77 shows that the rainfall differs very considerably in various parts of the United States. It is as high as 100 inches a year on some parts of the Pacific coast, and reduced in some places east of the Sierra Nevada to less than 5 inches per



F. Ellerman, Mt. Wilson Observatory

The four pictures show different types of clouds. The upper left hand are cirrus clouds; the upper right hand are stratus clouds; the lower left hand are nimbus clouds; and the lower right hand are cumulus clouds. Can you tell what kind of weather each type of cloud indicates?

year. Twenty inches of rain a year is a minimum for dry farming, and a rainfall of 30 to 50 inches is best for the great cereal crops of our country.

A study of the cloud pictures will help us to use cloud observation in foretelling storms. Cumulus clouds, for example, may bring local storms, especially thunderstorms, but are not an indication of long-continued rains. They begin to form at the level where the rising column of air reaches a point where it will condense, and frequently extends into the atmosphere for a height of five miles or more. Cirrus clouds are light and feathery. They are formed at a very great height, and are usually composed of tiny crystals of ice. Stratus clouds are rather low, lying in long horizontal beds, and are much more likely to indicate rain. Nimbus clouds almost always bring rain.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences on page 64 and arrange them in proper numerical order. The same word may be used more than once.

thermometer
moisture
less
clouds
saturation
snow
expands
hygrometer
humidity
cools
barometer
dew
relative
saturated
holds
water
amount
actual
addition
low
contracts
high
raised
absolute

When air holds all the (1)____ it can, it is (2)____. When the capacity of the air to hold moisture is twice the (3)____ of moisture the air actually (4)____, its (5)____ (6)____ is 50 per cent. When air is warmed, it (7)____ and becomes (8)____ dense. Its density is also lowered by the (9)____ of (10)____. When warm, moist air rises high above the earth, it (11)____ and (12)____, and if it cools below the (13)____ point, (14)____ will be formed. Clothes will dry better if the relative (15)____ is (16)____; they will not dry at all if the air is (17)____. Weather instruments are: the (18)____, to measure humidity; the (19)____, to measure pressure; and the (20)____, to measure temperature.

PROBLEM TEST

Suppose that the relative humidity of the air in the room is 60 and the temperature is 90° F. The temperature drops to 80° F., but the amount of water in the air remains unchanged.

I. *A review of page 59 will help you to answer these questions.*

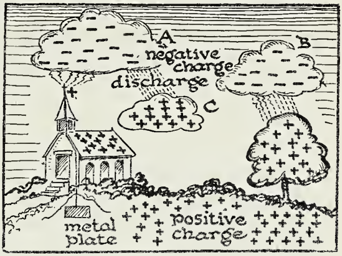
1. Will the relative humidity remain the same?
2. Will the relative humidity be greater?
3. Will the relative humidity be less?
4. Will the absolute humidity remain the same?
5. Will the absolute humidity be greater?
6. Will the absolute humidity be less?

II. *Which of the following facts and principles did you use in arriving at your conclusion?*

1. The absolute humidity is increased by evaporation.
2. When air is cooled below the dew point the absolute humidity is decreased by condensation.
3. The dew point is that temperature at which air is saturated.
4. Saturated air has a relative humidity of 100.
5. With a given amount of moisture in the air, relative humidity becomes less with a rise in temperature.
6. With a given amount of moisture in the air, relative humidity becomes greater with a fall in temperature.
7. When saturated air is heated, the absolute humidity does not change materially.
8. When saturated air is heated, the relative humidity is decreased.

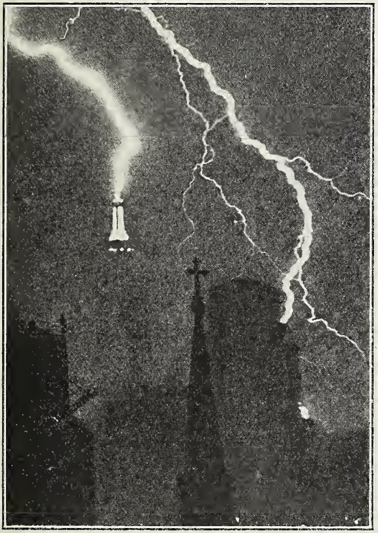
PROBLEM IV. WHAT ARE THE CHARACTERISTICS OF OUR COMMON STORMS?

Thunderstorms. There are two general types of local storms, thunderstorms and tornadoes. Thunderstorms are phenomena common to most of us. They are rarely more than 20 to 25 miles in width and travel as a rule not over 150 to 200 miles.



Electrical discharges. If *A* and *B* were much nearer would there be a discharge between them? What will be the effect of a discharge between *A* and *C*? Discuss the possible action between the clouds and the bodies on the earth.

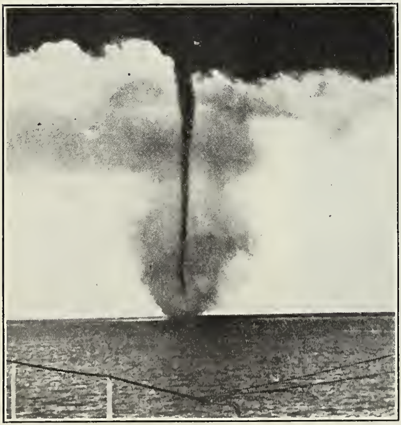
Electricity seems to be present in the air to a height of many miles. Less than 200 years ago Benjamin Franklin drew electricity from the sky and established its identity. During clear and dry weather, the amount of electrical energy in the air is fairly equally distributed. During hot weather, when the excessive moisture in the air is condensed very quickly and currents of air are moving rapidly, the particles of dust and moisture in a cloud become charged with electricity. As these particles combine, their electrical charges unite and raise the electrical pressure. The earth below will have an opposite charge induced in it, and objects attached to the


Wide World

Lightning striking the Empire State Building. This building, the tallest in the world, is a great lightning attractor. Do you see why?

earth, as houses, trees, and poles, will be charged the same as the earth. The dry air between the earth and cloud acts as an insulator, but if the charges become powerful enough to overcome the air resistance or if the clouds come near enough to the earth, a discharge results in the brilliant and familiar flash of lightning. The heat causes the air along its path to expand. The quick cooling that follows produces a vacuum. The sudden rush of air, driven by atmospheric pressure into this vacuum and the consequent hitting of the air molecules as they meet, produces a sound which we call thunder. The rumbling and prolongation of the sound comes from the fact that sound travels only one fifth of a mile a second. Therefore, the sound from the distant part of a flash does not reach us as quickly as that from the near-by part. In addition, the sound is reflected from clouds and comes to us as echoes. The distance of lightning from you can be estimated roughly by allowing one fifth of a mile per second for the time elapsing between the flash and the time you hear the thunder.

Tornadoes. Tornadoes usually occur along the valleys of the Missouri and Mississippi rivers, and occasionally in some parts of the Ohio Valley, as well as in the south and east. They are local storms, frequently varying from 50 to 1000 feet in width and traveling distances from 1 to 20 or 30 miles or, in rare instances, to 200 miles. A whirling motion develops in the rising column of air, and when it reaches a great intensity, the characteristic funnel, which is only a part of the cloud itself, is formed. Air is believed to rush around in this whirlwind at the rate of 300 to 400 miles an hour, and wherever the funnel of

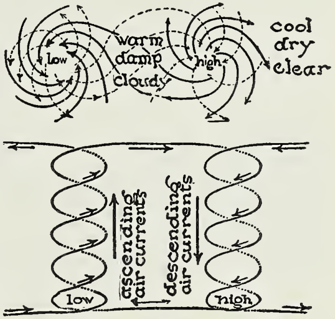


R. I. Nesmith

Waterspouts and tornadoes are formed in the same way, but the latter do much more damage. Why?

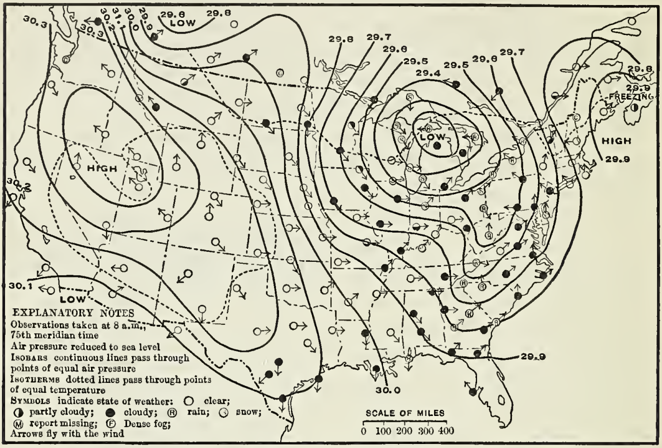
the tornado touches the ground, it sucks up and destroys everything in its path. Houses are actually blown inside out, because the low pressure outside the house causes the air inside to force the walls and windows outwards. Frequently a heavy fall of hail with thunder and lightning accompanies the tornado. Much damage is done by these storms, although fortunately they are restricted to comparatively small areas.

Winds and Their Causes. If we make a study of the weather map on page 68, we notice wherever the air pressure is low that little near-by arrows point approximately toward that spot. If we observe the map carefully, we see that these arrows indicate that the wind is moving spirally counterclockwise around this point of low air pressure. This rotary motion around and towards a low-pressure area is called a *cyclone*. Areas of high pressure, known as *anticyclones*, show just the reverse of the cyclonic movement of air, since the winds move away from these areas. The cyclonic movement of air is sometimes interfered with by local conditions, such as the unequal heating of land and water, or the presence of hills and mountain ranges which causes the air to move in irregular directions. Practically all our variable winds are caused by natural convection currents in the atmosphere. The trade winds and prevailing westerlies are influenced largely by the rotation of the earth in addition to convection.



Read your text and explain this diagram.

Comparison of High and Low Areas. Most of our storms which move across the country in more or less regular paths are cyclones. Areas of low pressure have high temperatures and high humidity. High-pressure areas have low temperatures and low humidity. Warm air is lighter than cold air. Moist air is lighter than dry air. These facts explain in part the existence of low pressures and high pressures. The heavy, dry, cold air of the "high" is drawn down by gravity with greater force than is the moist, warm air of the "low" and so the cold air flows in under the warm air


30.3
30.3
30.2
30.1
30.0
29.9
29.8
29.8
LOW
29.8
29.7
29.6
29.5
29.4
29.5
29.6
29.7
LOW
29.8
29.9
FREEZING
HIGH
29.9
HIGH
30.2
30.1
LOW
30.0
29.9
EXPLANATORY NOTES
Observations taken at 8 a.m., 75th meridian time
Air pressure reduced to sea level
ISOBARS continuous lines pass through points of equal air pressure
ISOTHERMS dotted lines pass through points of equal temperature
SYMBOLS indicate state of weather: ○ clear; ◑ partly cloudy; ● cloudy; Ⓡ rain; Ⓢ snow; Ⓜ report missing; Ⓕ Dense fog;
Arrows fly with the wind
SCALE OF MILES
0 100 200 300 400

What kind of weather do you think New York, Chicago, and Los Angeles would be having, according to this map?

and lifts it. About the center of the "low" there is always an ascending current of moist air; and about the center of the "high" there is a descending current of dry air. Complete convection currents are thus established. At the surface of the earth there is a movement of air or wind from the "high" to the "low." In the upper layers of the air above the earth there is a current of air from the "low" to the "high," thus completing the circuit of moving air.

Cyclonic Storms. If we study a series of weather maps and follow a low area from day to day, we shall find that in general these cyclonic storms pass across the United States from the northwest, southeasterly to the Mississippi Valley, then northeasterly, leaving the continent along the St. Lawrence Valley. These storms move rather slowly, at the rate of about 25 miles an hour in summer and about 35 miles an hour in winter. These cyclones occur with considerable regularity in the winter, each cyclone being followed by an anticyclone or area of high pressure, from which winds blow in a clockwise spiral.

Observation of many maps will show that the southeast quadrant of the cyclone is the area most likely to get rain. In technical language, snow, hail, or rainfall is called *precipitation.* East and south or southeast winds, unless accounted for otherwise, indicate the approach of a "low," and so frequently precede rain or snow.

CONDITIONS IN CYCLONIC AND ANTICYCLONIC AREAS

	Area	Temperature	Moisture	Pressure	Wind	Air Current	Sky
cyclonic	low	warm	moist	low	inward	ascending	cloudy
anticyclonic	high	cold	dry	high	outward	descending	clear

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same words may be used more than once.

clouds
saturated
cylonic
precipitation
electricity
colder
moist
energy
damage
lightning
temperature
sun
air
local
warmer
tornadoes

The (1)____ provides the atmosphere with (2)____, which produces in various ways winds, clouds, and storms. Thunderstorms and (3)____ are two types of (4)____ storms which do much (5)____. A discharge of (6)____ through the (7)____ is called (8)____ and produces thunder. Our common periodic storms are (9)____ storms. In a low barometric area the air is (10)____, light and warm. It is in this area that we have (11)____ and 12____.

PROBLEM TEST

I. A cyclonic storm is approaching. The center of the low is a little north and west of you. What are the weather prospects?

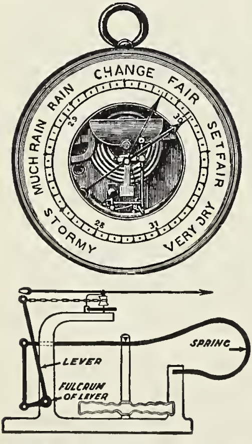
1. What will be the wind direction?
2. What will be the condition of the sky?
3. Is there likely to be either rain or snow?
4. Will the atmospheric pressure be low or high?

II. *Select from the following facts and principles those which you have used in answering the above questions and specify which question in each case.*

1. High pressure areas are fair weather areas.
2. Low pressure areas are storm centers.
3. The winds about "highs" are clockwise.
4. The winds about "lows" are counterclockwise.
5. The southeast quadrant of storm areas is most likely to have precipitation.
6. Storms generally move from west to east.
7. Winds blow from "highs" toward the "lows."
8. Air is rising at the center of a "low."
9. Air is falling at the center of a " high."
10. East, south, or southeast winds often precede precipitation.

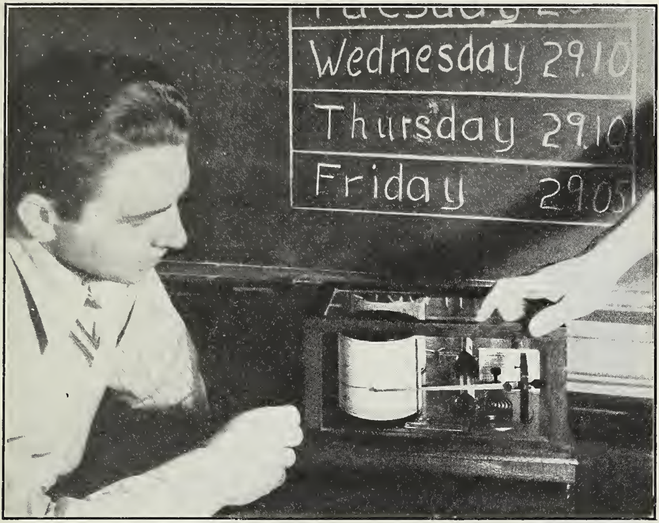
PROBLEM V. WHAT DOES THE WEATHER BUREAU DO FOR US?

Have you ever visited the weather bureau in any large city? If so, you doubtless remember the interesting trip taken to the top of a tall building where the government officials work with their various recording instruments. Here you saw barometers and thermometers, a wind gauge and rain gauge, anemometers and hygrometers. Perhaps you could not understand all of the instruments, yet you should be able to read and comprehend the maps which are sent out by the United States Weather Bureau, and which may be obtained by your own school for the asking. The life in your community is controlled to a very great extent by the weather you have; and the welfare of the people, especially outside of large cities, depends in part, on some knowledge of the weather. These changes in the weather can be predicted with a great deal of accuracy.



Explain the working of the aneroid barometer from this diagram.

Aneroid Barometer. The mercurial barometer cannot be carried about easily, as it must be kept in a vertical position. The aneroid barometer may be carried about like a watch or clock, and thus is used by explorers and for practical work in the field. Just inside



John Muir Technical High School

The barograph is a recording barometer. When is this more useful than the aneroid barometer?

the case of the aneroid barometer is a small flat box of thin corrugated metal. From this box some air has been removed. The walls are so delicate that a slight increase in pressure causes the walls to come closer together, while a decrease in pressure allows them to go farther apart. This motion is transferred by lever action to a hand which moves along a scale to show the pressure of the atmosphere. The aneroid is used both for weather observation and to measure the height of mountains or the altitude of aircraft.

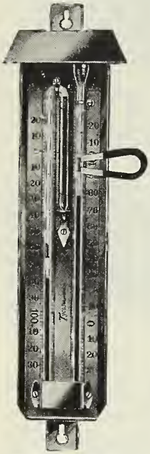
Demonstration 7. To Measure a Height with an Aneroid Barometer.

Study the scale and learn how to read fractions of a division on an aneroid barometer. Assume the relation of rise in altitude to the decrease in pressure to be 910 feet to 1 inch. Read the barometer at the base of a high building or better a high hill or small mountain. Carry the barometer to the top and read again. Read again at the top and again when reaching the base. Average the two readings taken at the base.

What is the difference in the readings taken at the base and at the top? What do you conclude to be the height of the building or hill?

The Barograph. The standard barometer for weather bureau readings is the mercurial barometer. But the aneroid is used in the self-recording instrument called the *barograph* shown on page 71. A pen which rises and falls under changes of air pressure records these changes on sheets of paper attached to the outer surface of a revolving drum, which is operated by clockwork.

Recording Temperatures. We have already learned that the centigrade thermometer is used in most scientific work, although the Fahrenheit thermometer is in common use, and is used by the United States Weather Bureau. Useful thermometers for determining extremes of temperature are of the self-registering type, shown here. In one type of *maximum* thermometer, the mercury pushes along a movable index placed inside the bore. When the mercury contracts, the index remains fixed, marking the point of greatest expansion. The *minimum* thermometer contains alcohol. When the alcohol contracts, the index is drawn downward and remains in place when the temperature rises. It is important for a study of weather conditions to have a continuous record of temperature. Such a record is produced automatically by an instrument called the thermograph.


Taylor Instrument Co.

A thermometer which registers maximum and minimum temperatures. What is it useful for?

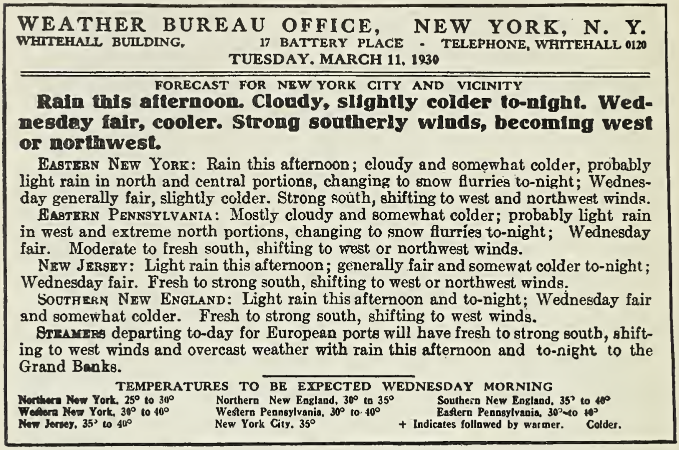
How Wind Velocity Is Measured. Wind velocity is measured by an instrument called the *anemometer*. This is an instrument in the form of a spindle, having arms with hollow cups on the end. The wind striking these cups causes them to revolve, and a certain number of revolutions per hour indicates one mile of wind velocity. The scale of wind velocity on page 73, called the Beaufort wind scale, issued by the weather bureau is used in publications put out by the weather bureau and will be found useful in working out home projects on weather.

Scale Numbers	Kind of Wind	Miles Per Hour
0.	Calm	From 0 to 3
1.	Light air	Over 3 to 8
2.	Light breeze	Over 8 to 13
3.	Gentle breeze	Over 13 to 18
4.	Moderate breeze	Over 18 to 23
5.	Fresh breeze	Over 23 to 28
6.	Strong breeze	Over 28 to 34
7.	Moderate gale	Over 34 to 40
8.	Fresh gale	Over 40 to 48
9.	Strong gale	Over 48 to 56
10.	Whole gale	Over 56 to 65
11.	Storm	Over 65 to 75
12.	Hurricane	Over 75

Formation of Dew. We have learned that after moisture has condensed into the clouds it may form drops of rain. In somewhat the same way moisture may be condensed on objects on the earth's surface and appear as dew. Vegetation, such as grass, holds little heat, losing it by radiation soon after the sun goes down. The grass thus cools the air immediately in contact with it, and the moisture in the air is condensed on the surface of the blade of grass.

Frost Warnings. When the temperature of the air is at the freezing point or below it, the particles of moisture, on condensing, form small crystals of ice or frost. Frost is an enemy of the farmer, and it can usually be predicted by the weather officials. The United States Weather Bureau, by means of its warning signals and reports, is able to inform farmers when frost is likely to occur, so that they may take proper precautions. In Florida and California, where citrus fruits are grown, frost is often kept away by burning many heaters at night. This raises the temperature of the air near the trees several degrees.

The Work of the Weather Bureau. It can be seen from the foregoing paragraphs that through telegraphic communication with various parts of the country a weather bureau is able to tell in advance what weather may be expected. There are a large number of branches in various localities, and each day the weather factors, — temperature, rainfall, rate of wind, direction of wind, barometric pressure, and other necessary information, — are telegraphed to Washington and to all the different weather bureaus throughout the United States, and weather maps are completed within an hour after the time the information is received. These weather maps are soon sent by mail to places all over the country.



WEATHER BUREAU OFFICE, NEW YORK, N. Y.
WHITEHALL BUILDING, 17 BATTERY PLACE - TELEPHONE, WHITEHALL 0120
TUESDAY, MARCH 11, 1930

FORECAST FOR NEW YORK CITY AND VICINITY

Rain this afternoon. Cloudy, slightly colder to-night. Wednesday fair, cooler. Strong southerly winds, becoming west or northwest.

EASTERN NEW YORK: Rain this afternoon; cloudy and somewhat colder, probably light rain in north and central portions, changing to snow flurries to-night; Wednesday generally fair, slightly colder. Strong south, shifting to west and northwest winds.

EASTERN PENNSYLVANIA: Mostly cloudy and somewhat colder; probably light rain in west and extreme north portions, changing to snow flurries to-night; Wednesday fair. Moderate to fresh south, shifting to west or northwest winds.

NEW JERSEY: Light rain this afternoon; generally fair and somewat colder to-night; Wednesday fair. Fresh to strong south, shifting to west or northwest winds.

SOUTHERN NEW ENGLAND: Light rain this afternoon and to-night; Wednesday fair and somewhat colder. Fresh to strong south, shifting to west winds.

STEAMERS departing to-day for European ports will have fresh to strong south, shifting to west winds and overcast weather with rain this afternoon and to-night to the Grand Banks.

TEMPERATURES TO BE EXPECTED WEDNESDAY MORNING

Northern New York, 25° to 30°
Western New York, 30° to 40°
New Jersey, 35° to 40°
Northern New England, 30° to 35°
Western Pennsylvania, 30° to 40°
New York City, 35°
Southern New England, 35° to 40°
Eastern Pennsylvania, 30° to 40°
+ Indicates followed by warmer. Colder.

Information given by a weather bulletin. Does your school get this information daily? You can get such a bulletin regularly by applying to the Weather Bureau.

Advance information about the weather is of importance in transportation, in commerce, in industry, and to a degree in the control of our daily activities. While it is impossible at present always to make infallible predictions, over 80 per cent of the weather bureau predictions are correct.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

barograph
thermometer
storms
reports
seventy
thermograph
barometer
frosts
value
fifty
floods
centigrade
forecasts
eighty
clouds
temperatures

(1)____ sent out by the Weather Bureau are of (2)____ to mariners, farmers, and the general public because over (3)____ per cent of their (4)____ come true. The Weather Bureau sends out advance warnings about (5)____, (6)____, and (7)____. Two important self-recording weather instruments seen at weather stations are the (8)____ and the (9)____. Self-registering thermometers mark minimum and maximum (10)____.

PROBLEM TESTS

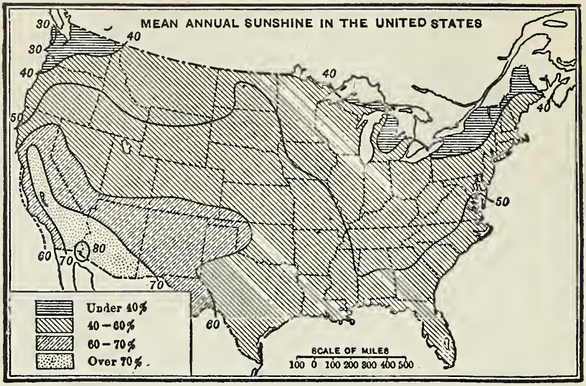
Tell what kind of weather you think will follow these observations which you have made.

1. It is cloudy with a small amount of rainfall. The wind which has been northeast slowly shifts to northwest.
2. The wind is from the east and increasing in strength. There are no dense clouds in the sky.
3. The "horns" of the moon are in such a position that the moon can hold water. In other words, it is a "wet moon."
4. There is a dense circle around the moon and two stars can be seen within the circle.
5. The barometer is falling very rapidly.
6. It has been a very hot day. Large masses of cumulus clouds are seen in the west.

PROBLEM VI. WHAT DETERMINES CLIMATE?

We often refer to the climate of a given place as dry, moist, hot, or cold. In Nevada, for example, they have a hot, dry climate most of the time, and in Florida, a warm, moist climate. Climate is defined as the average weather in a place over a long period of time. But there are certain factors in causing climate which vary greatly, depending upon the locality. The first agent involved in all weather and climate is the sun. It is the source, as we have learned, of all the heat upon the earth. Storms, winds, the growth of plants and of animals are all dependent in the long run upon the energy of the sun. But the factors which cause other great changes in climate are latitude, elevation, nearness to large bodies of water, such as lakes or oceans, and the presence of lofty mountains, especially mountain chains. All of these modify in a large measure the action of the sun upon a given locality.

Sunshine — a Factor in Climate. Sunshine in moderation makes our crops grow. It gives necessary warmth to the soil, so that the longer day in summer with its vertical rays of sunlight warms the earth, rendering it favorable for the growth of crops.

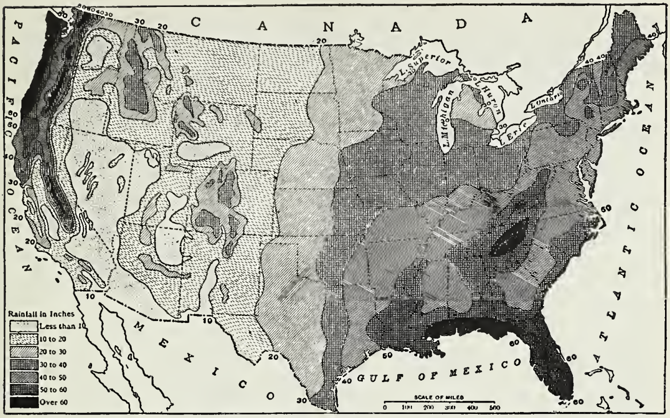


Sunshine map. Compare the amount of sunshine in northern California with that in Florida; that of southern California with northern New England. What is it in your state?

It is an interesting fact that in winter we are about three million miles nearer the sun than in summer. How do you account for its being colder in winter?

Rainfall a Factor. We have all seen that rain plays a very important part in the industrial life of a people. Rainfall makes possible a certain kind of community. Farming depends to a large extent upon the amount of rain and sun. If the summers are hot, rain is a necessity, both for the protection of the soil and for the growth of the plants. In the great Middle West, where the rainfall is from 20 to 30 inches a year, wheat is the staple crop, while in the East and South there are more diversified crops, because the rainfall is much greater, being between 40 and 70 inches.

Relation of Climate to Latitude and Altitude. We usually associate heat with the tropics and cold with regions far to the north and south of the equator. It is true also that at sea level, other conditions being equal, the higher the latitude, the colder it is. Within the torrid zone, in a band 3000 miles broad around the earth, we may find arid deserts, intense humid areas, a very hot temperature, and in very high altitudes small areas of perpetual snow. An altitude of 300 feet at the equator is equivalent to moving north or south 140 miles, with a resulting drop of about two degrees in temperature. There are mountain peaks in the


CANADA
PACIFIC OCEAN
L. Superior
L. Michigan
L. Huron
L. Erie
L. Ontario
MEXICO
GULF OF MEXICO
ATLANTIC OCEAN
Rainfall in Inches
Less than 10
10 to 20
20 to 30
30 to 40
40 to 50
50 to 60
Over 60
SCALE OF MILES
0 100 200 300 400 500

A map showing the annual rainfall in the United States. Where is the rainfall greatest. Where least? What areas are best fitted for growing crops? Where are forest areas likely to be found?

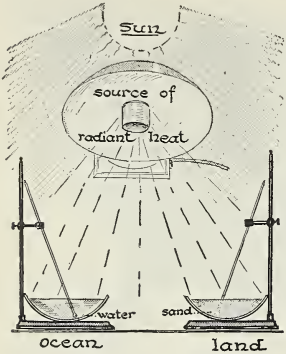
torrid zone that reach the line of perpetual snow. When the prevailing winds blow constantly in one direction over a high mountain range, the moisture in the air is condensed, producing abundant rainfall on the windward side, but on the other side the air is dry, and desert conditions may prevail.

Influence of Water upon Climate. It is not uncommon for us in the hot summer to make visits to the seashore or some mountain lake. Those of us who have lived near the seacoast or the shores of the Great Lakes know that the summers are much cooler and the winters somewhat warmer than they are in towns at some distance from these bodies of water. Along the shores of Lake Michigan and Long Island Sound an evening breeze from the water blows over the land, cooling and refreshing those who live there.

Demonstration 8. Unequal Heating of Land and Water.

a. Fill a saucer with dry sand or earth. Fill a second saucer with water. Keep both sand and water in the room until they are about the same temperature. Place these in direct sunlight and suspend a thermometer in each so that the bulb is just covered. Take temperature readings every 5 minutes. If the sun is not bright, throw rays from an electric heater or a 500-watt electric lamp equally upon them.

Take readings every 3 minutes. How does this experiment help you to understand a sea breeze?

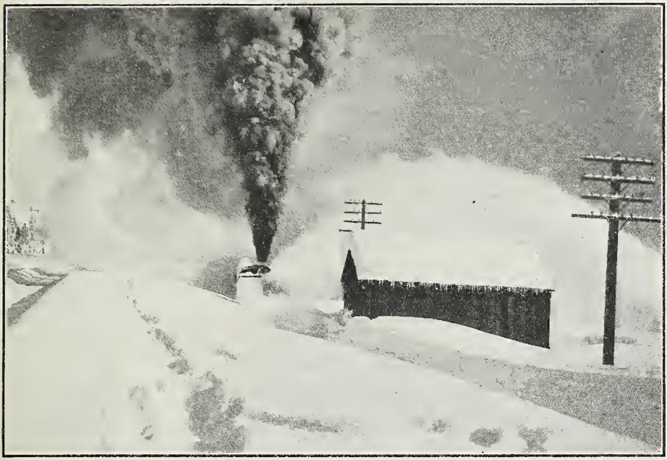


b. Transfer the two saucers from the hot radiations to a cold refrigerator. At intervals of 5 minutes take the temperatures. Which loses heat the faster? What winds do these facts help to explain?

If we think back to the heating of rooms, we recall that the stove set up convection currents in the room. The same thing occurs on a large scale between land and bodies of water. During the day the temperature of the land rises higher than does the temperature of the water of the lake. During the day the heated air above the land is continuously being pushed upward by the cooler and heavier air which comes in from the lake or ocean. In the evening, since the land cools more quickly than the water, the air from the land moves toward the water. In the winter months the lake or ocean loses its stored heat more slowly than the land and so prevents extremely low temperatures in its vicinity. Hence it is not uncommon to find no snow in New York City and along the sea coast, while less than a hundred miles from the coast it is several inches deep.

The Effect of Storms. The eastern part of our country owes much of its fertility to cyclonic storms. But prolonged and severe rainfall at times causes rivers to overflow their banks, doing much damage to crops, to buildings, and to railroads.

The railroad industry is greatly affected by cold weather and snowstorms. The snow blockades on the railroads of the northern part of the country have led to the construction of huge snow tunnels and wind breaks, and to the invention of the rotary snow plow. The freezing of harbors affects the commercial importance of a city, while, on the other hand, harbors which are located in regions where the trade winds blow constantly are much favored. Canada is much handicapped by the winter closing of the St. Lawrence River, while the ports of New York, Liverpool, and Buenos Aires are examples of favored localities.



Southern Pacific Lines

A rotary snow plow at work. Note the distance the snow is thrown to the right of the picture. Do some outside reading to find out how a rotary snow plow is constructed.

Industries Affected by Climate. Industries, such as farming or lumbering, depend largely upon climate. Many manufacturers, especially those who use raw materials of the forest or farm, build their factories near the source of supply. Others who make use of water power are also indirectly dependent upon the climate. More than this, workmen in factories, or indeed in any occupation, are very greatly influenced by climate. A recent study on the effects of temperature made by a committee on ventilation in New York state found that 15 per cent less work was done by a group of people working in a temperature of 70° F. than when the same group worked in a temperature of 68° F., while if the heat was as high as 86° F., they did 37 per cent less work than they did at 68° F.

Changes in Temperature in Relation to Community Life. Tropical climates or extremely cold climates are unfavorable in their effect on mankind. We have already spoken of this, and we know that northerners going into the tropics soon lose their ambition and settle down to a life of short hours of work. This seems to be caused by the lack of stimulation in such a climate. In the far North, long periods of darkness and the monotony of climate are unfavorable for the people living there. The moderate changes of a temperate climate, especially the cold winters and warm summers, do much toward making people active and resourceful.

What Is an Ideal Climate? From all that we have just learned, we are now ready to give some sort of answer to this question. The most favorable climate must certainly not be very cold or very hot. It must have some rainfall, at least 30 inches a year, to be ideal. We should be located near enough to large bodies of water so that we may benefit from their moderation of temperature and humidity. On the other hand, a high humidity, often found along bodies of water in summer, is uncomfortable. Frequently changes of temperature, such as mark the climate in most of the United States, are stimulating, and add to the total energy of the people. Above all, our climate should have a large number of sunny days, since health is one of the greatest assets to our community.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

energetic
changes
latitude
water
constant
climate
warmer
faster
snow
colder
nearness
altitude
stimulating
harmful
weather
depressing

The (1)____ of a place largely determines the activities carried on there. Climate depends chiefly upon (2)____, (3)____, and (4)____ to large bodies of water. Land breezes result from the land cooling (5)____ than the (6)____, but a sea breeze comes when the land is (7)____ than the adjoining body of water. A climate, with moderate (8)____ in temperature, is (9)____. The most (10)____ people are found in the north temperate zone.

PROBLEM TEST

Discuss the factors in climatic conditions which make Florida and California successful fruit-raising states. Compare sunshine, rainfall, and effect of latitude.

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. The following are some of the generalizations to which you may add others if you wish.

1. Air in motion can do work.
2. Compressed air can do many kinds of work.
3. Moisture, atmospheric pressure, and changes in temperature are important weather factors.
4. The sun controls all weather factors.
5. Storms result from certain combinations of weather factors.
6. The government sends out much weather data including forecasts.
7. Climate is the average weather over a long period of time.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × 2.*

I. **Moving air does work when:** (1) fog rises over a lake; (2) clouds are moved through the air; (3) an electric fan blows a wind; (4) it operates a windmill; (5) we use air in tires.

II. **Compressed air does work when:** (6) we pump air into a tire until it registers 35 pounds per square inch; (7) we use a vacuum sweeper; (8) a train is stopped by air brakes; (9) men use a pneumatic drill; (10) you meet a "head on" wind.

III. **The chief factor in causing water to become a part of the atmosphere is:** (11) reduction of atmospheric pressure; (12) winds; (13) heat; (14) clouds.

IV. **The chief cause of moisture separating from air and forming clouds is:** (15) mixing with cold air; (16) rising air expands and cools; (17) cold mountains; (18) moving over bodies of cold water.

V. **We are certain to have snow formed when:** (19) the moisture in the air condenses in a cloud at a temperature below 32° F.; (20) water from a rain cloud falls through a layer of air below 32° F.; (21) there is a full moon; (22) it is winter.

VI. **Cyclonic storm areas are characterized by:** (23) high temperature and high pressure; (24) low temperature and low pressure; (25) low temperature and high pressure; (26) high temperature and low pressure.

VII. **Evaporation of water into the air is favored by:** (27) a rise in temperature; (28) the presence of bodies of water; (29) high humidity; (30) foggy weather.

VIII. **The greatest destruction done by a tornado is caused by the:** (31) high winds; (32) high atmospheric pressure; (33) rain; (34) electric discharge.

IX. **The most important public work of the Weather Bureau is to:** (35) regulate the weather; (36) report the damage done by storms; (37) test weather instruments; (38) send out weather forecasts.

X. **Climate is influenced by:** (39) altitude above sea level; (40) nearness to ocean; (41) phases of the moon; (42) nearness to mountains.

XI. **The chief factor of weather and climate is:** (43) the ocean; (44) the sun; (45) the presence of trees; (46) the wind.

XII. **The weather most favorable to human energy is that which:** (47) changes frequently; (48) remains constant with little change; (49) is warm like that in equatorial regions; (50) is cold like that in Arctic regions.

PRACTICAL PROBLEMS

1. It is said that a free balloon carrying little weight will rise until it explodes. Explain how this can happen.

2. Explain the significance of the sign displayed at the rear of some auto trucks: "Danger, this truck has air brakes."

3. Trace the possible course of a molecule of water from a pond in North Dakota through various changes under the influence of the different weather factors until it eventually becomes a tiny part of a crystal of ice in the frost upon a blade of grass in Maine.

4. Does the replacement of a low barometric area by a "high" cause any other changes than in weather? Discuss each question as fully as possible. Suppose the low is 29″ and the high is 31″.

a. Will it cause you to weigh more or less?

b. Will it cause a boat to sink deeper in the water?

c. Will it change the pressure on the bottom of a lake?

d. Will it make a balloon rise faster? Higher?

e. Will it help the draft in your chimney?

f. Two one-liter bottles with stoppers are accurately balanced at time of a "low" on a very delicate balance. One bottle is kept tightly closed, the other has the stopper loosened. Will the balance be disturbed upon the arrival of the "high"?

g. Will dough for yeast bread rise just as high?

h. Will it affect the automobile gas engine mixture?

i. Will the height to which one can raise water with a lift pump be changed?

j. How will it affect your breathing?

INTERESTING THINGS TO READ ABOUT

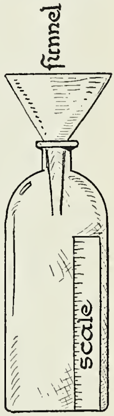
1. Windmills of today and yesterday.
2. Weather sayings which have some scientific basis.
3. How to interpret a weather map.
4. How a great under-river tunnel is built.
5. The benefits of compressed air.

LEISURE TIME ACTIVITIES

1. **Measure the rainfall.** Purchase a large tin funnel at the ten-cent store. Measure the diameter of the large open end. The square of the diameter in inches times .7854 equals area of top end of funnel in square inches. Find the inside diameter of a bottle as nearly as possible. Multiply the diameter squared by .7854 to get area of inside of bottle in square inches.

$$\frac{\text{Area of funnel opening}}{\text{Area of cross section of bottle}} = \text{The number of times the funnel area is that of the bottle area.}$$

If the funnel area is 10 times the bottle area, the rainfall will be one tenth of the depth of water actually collected in the bottle. If the funnel area is five times the bottle, the rainfall will be one fifth the depth of water in the bottle. A permanent scale should be made for your apparatus and pasted on the bottle so that it reads inches of rainfall without the necessity of any calculation. Cover the scale with shellac to protect it. Set the rain gauge in an open exposed place to catch the rain.

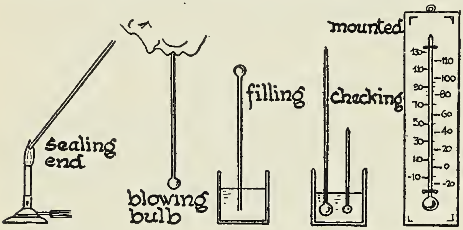


2. **Measure humidity in your house.** Get two ten-cent store thermometers which read exactly alike. Carefully cover the bulb of one with muslin, sewing it so it fits the bulb tightly. Dip the muslin-covered bulb into water; be sure the cloth is thoroughly wet. Swing it back and forth in the air in the room where the humidity is to be tested. Read its lowest point. Read the other thermometer. Refer to a table on page 60 for data by which to determine the humidity.

3. **Weather vane.** Devise a weather vane which will indicate the direction of the wind.

SCIENCE CLUB ACTIVITIES

1. **Make a weather thermometer.** Seal and blow a bulb in one end of a 10″ length of thermometer tubing having a bore 1 mm. Warm the bulb to expand the air. Dip the open end into colored carbon tetrachloride (or Carbona colored with iodine, or a red or blue dye). Some liquid should come up into the bulb. Hold the tube in a holder and heat (being careful not to point it toward anyone) until the liquid boils. Quickly dip the open end into liquid carbon tetrachloride. Repeat if necessary until the bulb is full. A small bubble of air can usually be shaken out and up the stem. All air must be out of the bulb and enough liquid in it to stand at least 1 inch above the bulb when cooled in ice water. Heat bulb in hot water to 150° F. or until the liquid is within an inch or two of the open end of the stem. Then seal end of stem in a flame. Now check with an accurate thermometer. Put both the thermometer and tube in ice-cold water. When the temperature is just 40°, make a file scratch on tube at level of liquid in stem. Place both tube and thermometer in water heated over 100° F. When the temperature has cooled to 100°, make a file scratch at level of the liquid. Mark off on a cardboard a space equal to the distance between the two file scratches. This represents 60°. Divide the degrees on this cardboard strip and extend the scale as far below 40° as the thermometer scale will allow. Fasten the scale to the tube so that the two file scratches on the stem correspond to the marks first made on your scale.



2. **Weather sayings.** Collect weather sayings. Have a report and discussion of these.

3. **Weather Bureau excursion.** If there is a government Weather Station near, get permission for your club to visit it.

4. **Advantages of one state over another.** Assign a state to each club member. After preparation each one will report the peculiar advantages of his state because of weather, climate, nearness to water, latitude, and altitude.

5. **Sailing.** A member who sails a boat may demonstrate how to operate a sailboat under different wind conditions.

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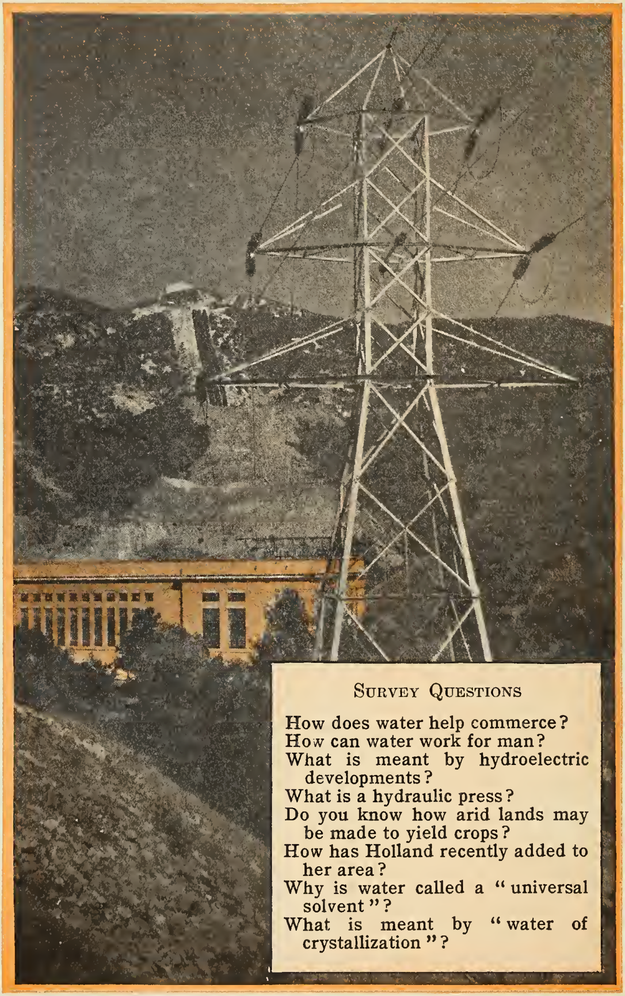


Survey Questions

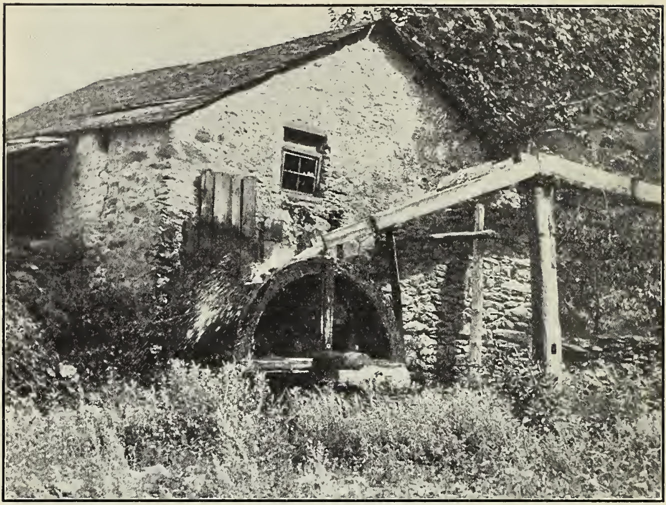
How does water help commerce?
How can water work for man?
What is meant by hydroelectric developments?
What is a hydraulic press?
Do you know how arid lands may be made to yield crops?
How has Holland recently added to her area?
Why is water called a "universal solvent"?
What is meant by "water of crystallization"?

UNIT IV

WATER A NATIONAL ASSET

PREVIEW

Water is a national asset. It is essential to agriculture and to many manufacturing and chemical industries. It provides power and offers natural waterways for boats. All of these are necessary for the growth of a nation. We think little of the solvent power of water, but the mineral matter found in a city water supply may prevent a certain industry from locating there. Water has played an important part in the preparation of most of our medicines and various chemical products. We know that energy is locked up in water because water has weight, and therefore can exert force. When water pushes on the blades of a turbine, or water wheel, it changes the energy stored in the water into action, and power is released. In early colonial times communities were often located around a mill situated on a swift stream. The mill ground corn or wheat, thus helping to prepare food for the community. Later more and more communities sprung up where water power was available. Thus we see in the Eastern states, where the greatest amount of available water power was early developed, that there are great numbers of manufacturing cities which in earlier times used to depend upon water power and which still use it. It is interesting to compare the early developments with those of water-power projects of today. When we think of such projects as the Keokuk dam or the great Muscle Shoals development, we realize what an enormous amount of energy comes from water power which is utilized. For example, Niagara Falls supplies over 1,500,000 horsepower, Keokuk 200,000, and Conowingo 600,000 horsepower. The total water power of the world is estimated at over 447,000,000 horsepower, of which over 46,000,000 is developed. Of the 38,000,000 horsepower in the United States, almost 16,000,000 horsepower has been developed. On the other hand, certain parts of Africa



Galloway

An old mill. Look on page 101 of your text and tell what kind of a wheel this is. Is much water power available here?

are estimated to have 125,000,000 horsepower, of which only about 250,000 horsepower has been developed. When we think of the work that is being done by water, especially in hydroelectric developments where electricity is produced, we realize that there are many possibilities of further utilization of this power in the modern world.

We also know that navigable waterways also determine the locations of great cities. Water also has a very direct relation to climate, and incidentally to the prosperity of the nation. Water plays a tremendous part in the growing of crops, as those know who have traveled from the green meadows of the mountains of California down into the desert only a short distance away. It is natural for man to transport water from places where it is plentiful to arid regions so that all may make use of the soil. In California thousands of acres of desert soil, rich in plant food, have been transformed into orchards of orange and lemon trees just by the application of water. The latest figures show that over 19,500,000 acres in the United States are under irrigation. This means that water has been brought from a distance to make possible the growth of living things in these areas. Over one billion dollars of the United States and private money have been put into these irrigation developments.

Before continuing your study of this unit, refresh your memory a bit by trying to recall as much as possible about the following general science principles which form the background of this unit.

1. Water exerts a buoyant or lifting force upon bodies in it.
2. Work can be done by a falling body.
3. Water is an essential factor in plant growth.
4. Matter varies in solubility from very soluble to insoluble.

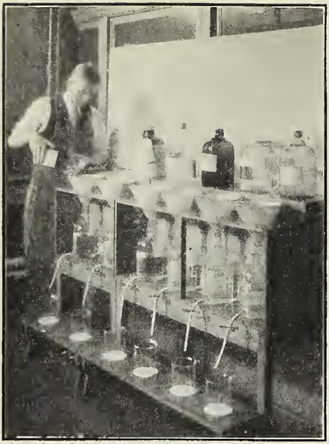
PROBLEM I. OF WHAT IMPORTANCE IS THE SOLVENT POWER OF WATER?

Water has been called a universal solvent because it is able to dissolve so many substances. The solvent power of water is useful not only in the distribution of food material in plants and animals, but also in large industries which utilize this property of water. Natural waters generally have substances in solution. In falling through the air rain dissolves gases, and water soaking into the soil dissolves mineral matter.

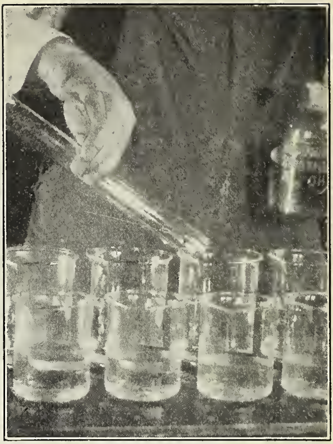
Demonstration 1. Hard and Soft Waters.

a. Permanent hard water. Prepare permanent hard water by adding a gram of calcium sulphate to a quart of water. The soap test for hardness is made by placing a piece of soap the size of a pea in a test tube one fourth full of water. Close the end of the tube and shake until a suds forms. It takes only two or three shakes to form a good suds with soft water. Boil a portion of the hard water for several minutes. To another test tube half full of hard water add $\frac{1}{8}$ teaspoonful of sodium carbonate. Shake to dissolve the carbonate. Make the soap test for hardness upon 3 samples: (1) the untreated hard water; (2) the boiled water; (3) the water treated with sodium carbonate. Did boiling remove the hardness? Did the sodium carbonate remove it?

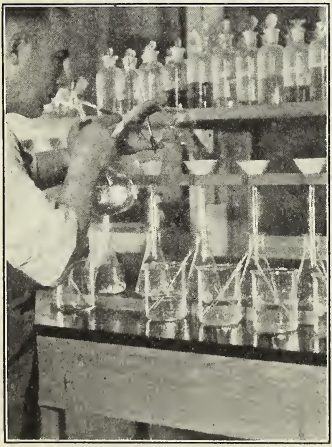
b. Temporary hard water. Prepare temporary hard water by passing carbon dioxide into limewater until the dense milkiness first produced clears perceptibly. Filter. The white solid first formed has the composition of marble. More carbon dioxide and water will



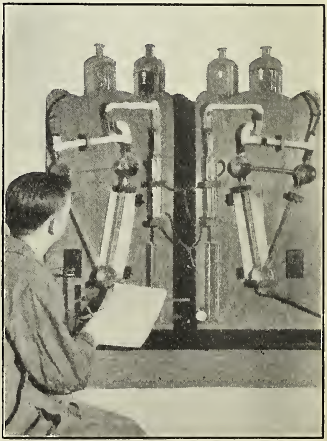
Filtering samples to remove suspended material.



Precipitating scale-forming ingredients by addition of chemicals.



Collecting the precipitates by means of filtration.



Travelers Indemnity Co.

Testing efficiency of treatments in model glass boilers.

How the chemist removes hardness from water and makes tests.

dissolve this just as limestone is dissolved in the earth. Boil a portion of the clear liquid for several minutes. Make the soap test for hardness upon two samples. (1) the clear liquid obtained by filtering; (2) the liquid after boiling. What are the results? Discuss the "hardness in water and how to remove it."

Boiler Scale. When a substance in solution is changed into an insoluble substance either by heat or chemical action, the substance, which separates into fine solid particles, usually slowly settles and is called a *precipitate.* The milkiness produced by breathing into limewater or by boiling temporary hard water is due to the formation of a precipitate. Precipitates are formed inside teakettles or hot-water pipes. If such a deposit forms inside the tubes of a boiler, it may cause a loss of efficiency in the boiler and may weaken the boiler tubes and may cause a serious explosion. The chemist can analyze water and tell how to treat it before it is used in boilers, as we see in the illustrations on page 90. In this way water may be softened and industry saved needless expense.

Hard and Soft Waters. Rain water has no mineral matter in solution and resembles distilled water in purity. These waters are called *soft waters.* Rain water does dissolve a little carbon dioxide from the air, and still more as it soaks through decaying vegetable matter at or near the surface of the earth. Carbon dioxide in water makes a weak acid. Limestone will dissolve in an acid. If water in passing through the soil comes in contact with limestone, it will dissolve some of it and this produces water containing mineral matter. Water containing certain minerals such as limestone or calcium, magnesium, or iron salts is called *hard water.* If the mineral salts separate from the water when the water is boiled, it is called *temporary hard water.* If not removed by boiling, it is *permanent hard water.* A permanent hard water can be softened by adding washing soda (sodium carbonate). The objection to hard water in the home and in laundries is that hard water will not easily make soapsuds. The minerals and the soap combine and the cleansing value of the soap is destroyed. Not until all the minerals in solution have combined with the soap can suds be produced. In many industries including the preparation of medicines the minerals present are objectionable because they may produce chemical changes with the compounds used in the water.

Water a Vehicle in Which Chemical Action Takes Place. We may think that a chemist dealing with chemicals in his laboratory would have little use for such a common substance as water, but as a matter of fact water is his most used substance. We may illustrate the value of water to a chemist by a very common household process, that of using baking powder in cooking.

Demonstration 2. How Water Aids Chemical Action.

1. Dissolve $\frac{1}{2}$ teaspoonful of baking soda in $\frac{1}{4}$ glass of water; dissolve $\frac{1}{2}$ teaspoonful of cream of tartar in $\frac{1}{4}$ glass of water. Pour one liquid into the other. Result?
2. Mix $\frac{1}{2}$ teaspoonful of baking soda (dry powder) with $\frac{1}{2}$ teaspoonful of cream of tartar (dry powder). Result? Pour the mixture into a glass half full of water. Result?

Solution Aids Chemical Action. In the solid state the molecules in these compounds are not able to act upon each other. But in solution the minute particles of solid are brought so close together, that they cause rapid chemical action.

Baking powder used in cooking contains solids like baking soda and cream of tartar. They are mixed with flour and water in bread-making or cake-making. The two solids do not react chemically in their dry state, but when their solutions are brought together, chemical action results. They may be mixed dry with flour, but only after water is added do they produce the gas that makes the dough porous and the bread or cake light.

When carbon dioxide dissolves in water, some of it combines with the water and makes a weak acid.

$$\begin{array}{ccccc} CO_2 & + & H_2O & = & H_2CO_3 \\ \text{Carbon dioxide} & + & \text{Water} & \text{produce} & \text{Carbonic acid} \end{array}$$

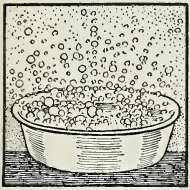
When calcium oxide (ordinary lime) is put into water, some of it combines with the water and makes a base.

$$\begin{array}{ccccc} CaO & + & H_2O & = & Ca(OH)_2 \\ \text{Lime} & + & \text{Water} & \text{produce} & \text{Calcium hydroxide} \end{array}$$

Calcium hydroxide in water solution is commonly called limewater. Chemically it is classed as a mild alkali or base.

What Are Acids and Bases? Acids and bases are chemicals whose properties are opposite. Acids are sour and bases are bitter; acids turn blue litmus red and bases turn red litmus blue. An acid will destroy the properties of a base and a base will destroy the properties of an acid. When acids and bases react with each other, two new products result. One of these products is always water and the other is a salt. Acids and bases in the right amounts neutralize each other and the process is called neutralization. A compound which does not change the color of litmus is neutral.

Salt. There is one salt you are very familiar with. How many times have you said, "Please pass the salt"? Hydrochloric acid is a gas in its pure state. The chemist uses a water solution of it. Its formula, HCl, shows it to be a compound of hydrogen, which is a harmless gas, and chlorine, a poisonous gas. Sodium hydroxide, or caustic soda, is a solid whose formula is NaOH. You see here the common harmless elements oxygen and hydrogen combined with sodium. The latter is an element so active that a tiny piece of it placed on any wet substance will generate the gas hydrogen and set the substance on fire. Obviously we would not want to put it into our mouths.



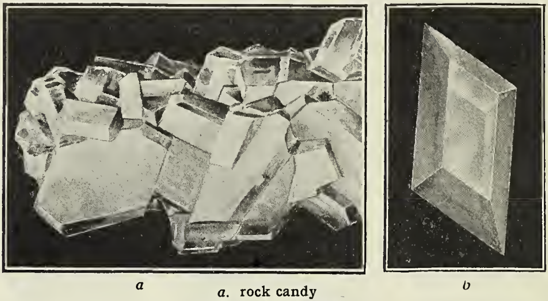
The action of sodium on water.

Chlorine gas attack.

Using sodium chloride as a food.

When these two compounds — the acid and the base — are brought together, the harmless elements combine to form harmless water and the two dangerous and poisonous elements, sodium and chlorine, also combine. Strangely enough they, too, form a harmless compound, common salt, which is known to the chemist as sodium chloride.

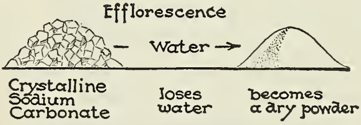
Water of Crystallization. Many compounds held in saturated solutions will form crystals as the water slowly evaporates. Some substances, like washing soda and baking soda, form a loose compound with water. This water is essential to the crystal form, Water thus held in combination is known as the water of crystallization. When clear glass-like crystals of washing soda are exposed to the air for a long time, they lose their glassy luster and eventually crumble to a dull white powder. This is due to the loss of the water of crystallization which makes up more than half its weight. After losing this water the salt is said to be *dehydrated.*



a. rock candy
b. washing soda

What other crystals have you seen? Do they all hold water of crystallization?

Purification of Salts. Many salts after being dissolved in water will separate in crystal form if the water is slowly evaporated. The ones that are less soluble make crystals first. Crystallization is therefore a purification process by which one salt can be separated from others. There are many salts in sea water. If you evaporate sea water, you can see the cubical crystals of salt forming, but they may enclose small amounts of other salts. If we dissolve the crystals first formed in pure water and recrystallize them, each time the process is repeated, the purer the crystals become. This process of purification is very important in many chemical industries. Much common salt is found in the mines pure enough for use, but impure salt can be purified by crystallization and recrystallization.

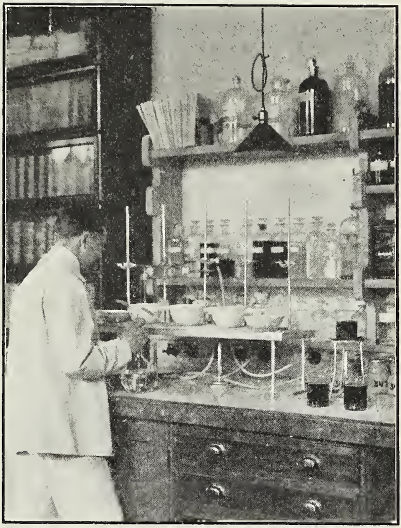


This shows how a salt becomes dehydrated.

Solution Aids in Many Chemical Processes. As we have already shown, chemical changes are often aided by water solution.

Advantage of this is taken in many chemical industries as for example the preparation of saltpeter. In this process the elements present may form several compounds which vary widely in their solubilities. Those least soluble can be separated by crystallization.

Without the aid of water solution the chemist could do very little. His testing solutions are largely water solutions. He also takes advantage of the solubility of some substances and insolubility of others. You have already seen an example of this in the test for carbon dioxide. Calcium hydroxide (limewater) will dissolve in water. When this acts chemically with carbon dioxide, calcium carbonate, which is insoluble, is formed. Since it is not dissolved, it separates out and becomes visible. This method of producing insoluble products is used frequently in testing. The science of chemical analysis is in large measure based upon this principle.



The chemist at work. How many of the pieces of glassware and apparatus have you seen? How many can you name?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once if necessary.

hard
acids
salt
bases
salts
retards
soft
crystallized
crystals
purified
dehydrated
recrystallization
removed
aids
crystal
ability
temporary
solution
action
neutralize

Water that contains calcium (1)____ is a (2)____ water. If the (3)____ can be (4)____ by boiling, it is a (5)____ hard water. Solution (6)____ chemical (7)____. Acids have the (8)____ to (9)____ bases and form water and a (10)____. When some salts separate in (11)____ form from (12)____, they combine with water which becomes a part of the (13)____ salt. If the salt loses this water on exposure to the air, it becomes a (14)____ salt. Many salts are (15)____ by (16)____.

PROBLEM TEST

1. You are camping on the shore of a lake and have no way of getting store supplies for a week. The first day, in taking salt to the fire on the beach where you cook, all the salt is accidentally spilled. What will you do?

2. You notice that when you wash in the lake, using soap, that a scum forms but no lather. How can you determine whether there is any remedy other than using washing soda?

3. After a rainy day at camp, you discover that the cover to the baking powder can was left off and rain water has leaked in. You spread the wet baking powder out in a pan and dry it over the fire. It cakes and gets hard, but you pulverize it and it looks as good as ever. Explain why you think it *will* or *will not* make good biscuit the next time you use it.

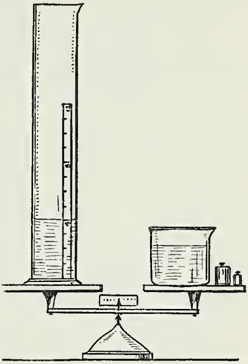
PROBLEM II. HOW IS WATER PUT TO WORK?

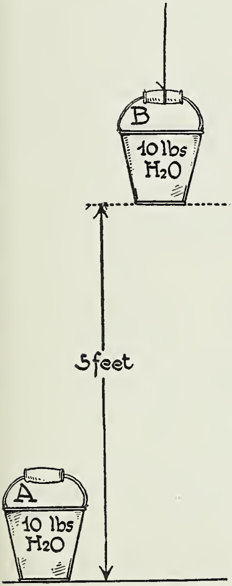
Energy Stored in Water. We have already seen that a falling body can do mechanical work. Mechanical energy may be of two kinds. If the water is in motion, it has *kinetic energy*. If the water is at rest but elevated so that it can work when allowed to fall, it has *potential energy*. By the way, do you recall what the unit of work is? A foot pound is the work done in overcoming a resistance equal to lifting one pound of matter one foot high against gravity. Water, as you know, is taken into clouds by the sun's heat and then acts as a falling body in flowing back into the ocean from high altitudes. Thus it can be harnessed to do work, and by building dams for storage, it may work continuously. All water stored in reservoirs and capable of falling to lower levels when released has potential energy and when it does fall it releases kinetic energy. Water in situations like this provides us with water power.

Demonstration 3. Relation of Water Pressure to Depth.

Exactly balance an empty cylinder (12″ to 20″ tall) on a platform balance by adding water to a beaker. Pour in water to a measured depth, say 4″. Measure the depth with a ruler held inside the cylinder. Hold eye on level of the water and read the under surface of the film. Find out how much this presses downward to the nearest gram by adding weights to restore the balance. Add water to double the depth. Find out how much this presses downward. Increase the depth three times. Result.

Does there appear to be any relation between the depths of water and the downward forces exerted which would suggest a law? If so, formulate the law covering the relation of water pressure to depth as it appears to you.





In which pail is the water capable of doing the more work. Read the text and explain.

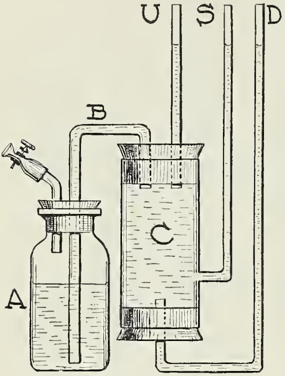
Importance of Height of Fall. The demonstration has shown a very important principle. The pressure of water varies directly as its depth. Water which has a drop of 40 feet can do twice as much work as it could with a drop of 20 feet. It is not the quantity of water back of a dam that determines the energy that can be obtained, but it is the amount of water that flows to the water wheel and the distance that it falls.

What Is Pressure? The word "pressure" is often loosely used as we use the word "force," but in science its real meaning is limited to force on a unit area. Thus atmospheric pressure is 15 pounds per square inch. To say that the pressure of water in a confined space is 1000 pounds means that it is 1000 pounds on one unit area, the unit commonly being a square inch. A steam pressure of

200 pounds in a boiler is a pressure of 200 pounds on each square-inch area.

Demonstration 4. External Pressure upon Confined Water.

Close one end of a glass tube 8″ long and about 1″ in diameter with a stopper. Heat a small spot on one side with a blowpipe flame and blow a hole through. Enlarge the hole carefully with a round file, holding it under water while doing so. Make the hole large enough to insert a glass tube with a piece of rubber tubing around it to make a water-tight connection. Complete connections as suggested in the diagram. Fill bottle *A* and tube *C* and connecting tube *B* with water. The levels of the water in tubes *U*, *S*, and *D* depend upon the pressure.



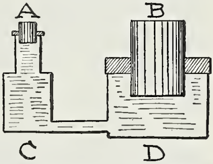
Are the water levels in *U*, *S*, and *D* the same before more water is pumped into *C*?

By means of an air pump, force air into *A*, thus pushing water under pressure into *C*, or blow breath into *A* without using the pump. Close the clamp. The water in *C* is now subjected to external pressure.

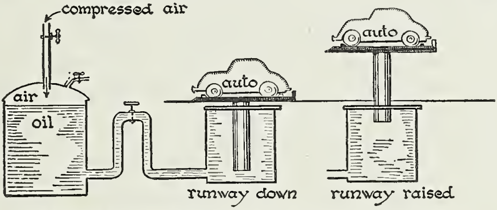
Is this pressure communicated to all surfaces of *C* equally? What is the evidence about its being communicated upward, downward, and to the side? Formulate a law relating to the carrying of external pressure by a confined body of water.

Hydraulic Press. Water can also be used in other ways to do work, as for example in the hydraulic press. The principle used here is this: that external pressure applied to a confined liquid is transmitted undiminished to every equal area of the containing vessel. Suppose you have a tank connected with two pistons whose areas are respectively 1 square inch and 100 square inches. Here it will be seen that since pressure is transmitted equally in all directions by a liquid, if you exert 1 pound pressure on the small piston of 1 square inch in area it will exert 100 pounds pressure on the larger piston whose area is 100 square inches. Thus by exerting a force of 1 pound, a corresponding force of 100 pounds can be put on the larger piston. This law of transmission of pressure in liquids has been applied in such devices as the hydraulic elevators, and hydraulic jacks such as are used for raising automobiles for working under the car. Hydraulic presses are used in baling cotton and in other industries where high pressure is required.

The Automobile Lift. An automobile, supported as high as a man's head on a runway by a single steel cylinder, is a familiar sight at many filling stations. The automobile is lifted so that men can work under it comfortably. The automobile lift works on the same principle as the hydraulic press. Suppose a liquid fills the space *CD*, and a piston *A*, having a lower end area of 1 square inch, as in *C*, and a plunger *B*, having a lower end area of 50 square inches, as in *D*. Whatever pressure *A* exerts downward on the liquid in *C* is given to every square inch of *B* that is in the liquid in *D*. The side pressures are balanced, but the upward pressure, being 50 times that at *A*, can lift a heavy load. A downward force of 100 pounds at *A* would give an upward force of 5000 pounds at *B*. The automobile lift uses oil for the liquid. The force to push down on the oil and carry the oil over from the tank to the lift chamber is obtained by the use of compressed air. The operation of this lift can readily be understood by a brief study of the two diagrams.



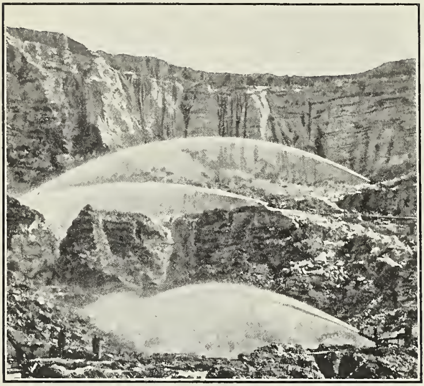
Read the text and explain this diagram.



Explain with reference to the text how the auto lift works.

Water Used in Mining. In many parts of the country water has been used under pressure to excavate pits, and particularly to wash gold out of gravel beds. In California whole mountain sides were washed away through the energy of great streams of water directed through nozzles against the side of the mountains. Similar energy is seen in the high-pressure lines in cities.

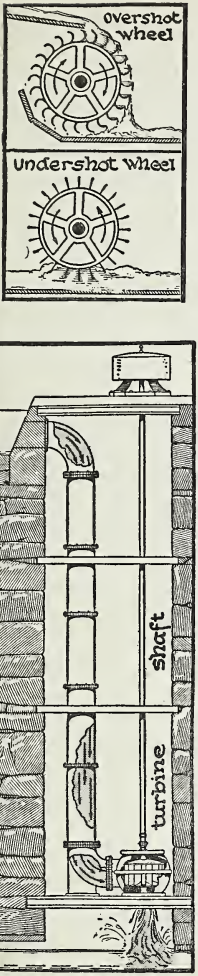
Water Power. The rate of doing work is measured in "horsepower," which is discussed more fully in Unit VIII. It is sufficient now for us to know that one horsepower is equivalent to 33,000 foot pounds per minute. We have already seen that about 447,000,000 horsepower of water is available for use in the United States but unfortunately the flow of water varies greatly at different times of the year. In the Tennessee River at Muscle Shoals, for example, in March the peak of the daily flow is 481,000 cubic feet per second, while in the months of September and October it is less than 10,000 cubic feet per second. This would mean a potential horsepower of nearly 5,000,000 at the peak of the flow and less than 100,000 at the low point. Reservoirs, therefore, which will control the water supply are obviously necessary if we are to develop the energy locked up in water. For a given amount of water the energy depends upon the *head*, which is a term meaning the vertical distance through which the water can fall.



Gabriel Moulin

Hydraulic mining in northern California. This great force is obtained by bringing the water from mountain streams through long pipe lines to the river valley.

How We Get the Energy Out of Water. From early times water wheels have been used to develop the energy found in water. Three types of wheels have been developed, only one of which is much used today. The undershot wheel was used where water was abundant and little fall occurred; the overshot wheel was seen in the old mills where the fall was considerable but the amount of water not great. Both of these wheels have given way to the turbine. The turbine wheel is enclosed at the base of a closed pipe called the penstock, which brings the water from an upper level down to the turbine. The wheel is so set that the water

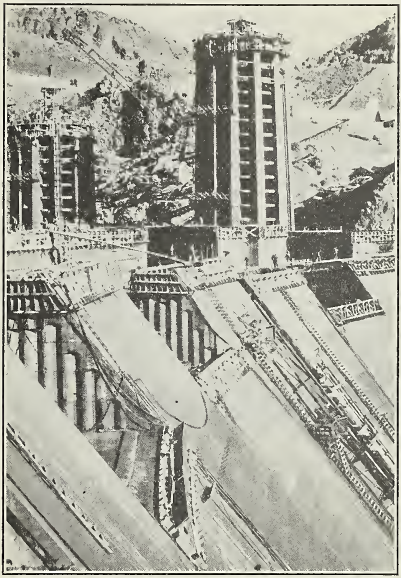


Types of water wheels. How does each one work? Which is the most efficient?

under considerable pressure strikes the thin curving blades, thus utilizing as much as 90 per cent of the energy in the water.

Hydroelectric Plants. All the great hydroelectric developments today use the turbine. A water turbine is used to operate the great electric generators at Niagara Falls, where the 160-foot drop is utilized for developing about 1,500,000 horsepower if we count all the power plants on both sides of the falls. In some of the power houses in the Far West, water flows through penstocks from an elevation of 2000 feet, and when it strikes the turbines, it has a velocity of over 240 miles an hour. Thus it develops a high horsepower from a relatively small stream. The so-called Tennessee Valley Authority plans to build about 100 dams on the Tennessee River between Muscle Shoals and Chattanooga. This project is expected to produce 4,000,000 horsepower. The energy may be transmitted to cities hundreds of miles away by means of high-tension lines. These wires carry currents of high electric pressure, or high voltage.

The Boulder Dam Project. Anyone who visits the wild, rocky Black Canyon during the building of Boulder Dam will go away impressed with the fact that here in a wilderness of rock and desert, man is building the greatest hydroelectric station in the world besides controlling a river which in past years has done enormous damage by flood and erosion to the valley miles below the new dam. The Boulder Dam project has a triple value. First of all, it will control the muddy Colorado River by forming a huge lake 115 miles long which will hold water enough to cover the entire State of New York to a depth of one foot. The water thus held back will be fed out through the penstocks of the great dam, to the turbines, there to develop 1,200,000 horsepower. But this is only the beginning of the values from the project. Not only will cheap illumination and power be sent to the cities along the west coast of California, but this power will also be used to pump water over the mountains in the new 241-mile Colorado River Aqueduct which will supply Los Angeles and near-by cities with water. The water which passes out of the penstocks will be regulated and, to some degree, cleaned of its load of silt, so that it can be given in a steady flow all the year round to the Parker Dam 125 miles below on the Colorado River. This dam will supply water to the new Colorado River Aqueduct. But this is not all that the Boulder Dam will do. Large level areas of rich soil of the Imperial Valley are now irrigated, but the Colorado River is so full of silt and its flow so irregular that it is difficult to control the irrigation in this region. The dam will hold back water for dry seasons, and in the great reservoir much of the silt and mud which has made so much trouble in the past will settle. Thus the Boulder Dam project supplies power, controls the water supply, and reduces the danger from the Colorado River by silt and erosion. It should soon repay for its construction in its conservation values.



R. I. Nesmith and Associates

Boulder Dam in November, 1934. What is the use of the towers? How much of the dam is shown here?

Co-ordinating Hydroelectric and Steam-Electric Plants. The Conowingo Dam across the Susquehanna River in Maryland has a capacity for operating eleven 54,000-horsepower turbines. These drive generators that produce electricity which is supplied to Philadelphia 70 miles away. But the flow of the water varies from 2200 cubic feet per second during dry summers to a maximum of 750,000 cubic feet per second during the spring floods. As a rule, the heavy load of lighting and power will be carried by the hydroelectric plant, and steam will be used to carry the peak load, but in the dry season, the steam plants of Philadelphia will carry the base load, using the water to care for the peak load which comes in the evening. This arrangement saves 750,000 tons of coal a year, and an investment of $20,000,000 in steam plants.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

water
rising
open
62.4
33,000
10
550
device
undershot
high
confined
fall
penstock
directions
falling
generator
pound
pressure
minute
all
device
electricity
second
turbine

Water at a (1)____ level capable of (2)____ ten feet can do (3)____ foot pounds of work per (4)____ if allowed to (5)____. A standard horsepower is (6)____ foot pounds of work per (7)____. The most efficient (8)____ for getting energy from (9)____ is the (10)____. As a rule, the turbine is connected to a (11)____ from which (12)____ is delivered. Water in a (13)____ space transmits (14)____ equally in (15)____ (16)____.

PROBLEM TEST

When a hydraulic press is used in baling cotton, there are several reasons why a small effort can overcome a very large resistance. Separate the following statements into two groups — *significant*, or those which are made use of, and *irrelevant*, or those which are not in any way used in the action of the press.

1. Water is less dense than mercury.
2. Water is incompressible.
3. Water can change its form or shape readily.
4. The pressure in water varies directly with the depth.
5. Water can communicate external pressure undiminished to all equal areas.
6. The effort piston is smaller than the resistance piston.
7. The pressure of the atmosphere averages 15 pounds per square inch.
8. One cubic foot of water weighs 62.4 pounds.
9. The small piston moves through a greater distance than the large piston.
10. The pressure per square inch is the same on both pistons.

PROBLEM III. HOW DOES WATER AID SHIPPING?

It seems a far cry from the discovery of the old Greek mathematician, Archimedes, to the modern steamship, and yet his discovery of the significance of density has made it possible for the world to build boats and carry cargoes. Let us interrupt our story of the uses of water for a moment to see if we can understand how ships stay on top of the water.

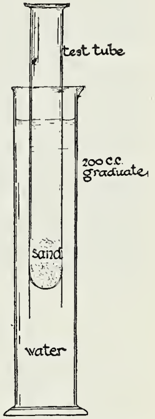
Why Things Float. The story goes that King Hiero of Syracuse had a crown wrought by one of his goldsmiths, which he suspected was not made of pure gold. He asked Archimedes to discover if the crown contained any other metals, but he would not allow him to bore into it or mar it in any way to find out. The philosopher, while taking a bath one day, noticed that his body displaced a certain amount of water, and seemed to be buoyed up by it. Seeing the significance of this, he applied it to the problem of the crown, and overjoyed he rushed from his bath without thinking of clothes, and ran into the street crying, "Eureka! Eureka!" which means, "I have found it! I have found it!" He had really found the solution of his problem. By weighing the crown in the air, and then in the water, he found how much it lost when weighed in water. This loss was due to the lifting force of the water and was equal to the weight of water displaced. The volume of the water displaced was, of course, the volume of the crown. The weight of the crown in air divided by its volume gave its density, since density is the weight of one unit volume. The density of pure gold being known, it was an easy matter to compare the density of the crown with that of pure gold and to detect any fraud of mixing lighter metals with the very heavy gold. The principle of buoyancy [1] thus discovered is stated. *A body immersed or floating in a liquid is held up with a force which is equal to the weight of the liquid displaced by it.*

Demonstration 5. How Does Water Buoy Bodies Up?

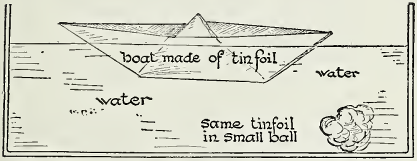
1. Add sand to a test tube having a capacity of 40 or 50 c.c., until the total weight — sand and test tube — is exactly 30 grams. Fill a 100 c.c. cylindrical graduate to the 60 c.c. mark. To read the water level, hold the eye on a level with the water surface and read the lower surface of the film you see. Float the tube of sand in the water and notice how much water is displaced by reading the new water level.

2. Balance exactly a dry 25 c.c. graduate on the scales. Fill with water to the 25 c.c. mark. How much does the weight increase? What is the weight of 1 c.c. of water?

Conclusion. What is the weight of the water displaced by the 30-gram floating body in the first test? How much water would be displaced by a floating body weighing 100 grams? Make a general statement concerning floating bodies.



Buoyancy. When we say a substance is buoyant, we mean that it is lighter than the same bulk of water, and therefore floats. The term *buoyant* is also applied to the liquid which holds up a floating body. The lifting force of water upon a body, *no matter whether this body sinks below or remains on the surface,* is called the *buoyant force* of water. This is equal to the weight of the water displaced. Every cubic foot of



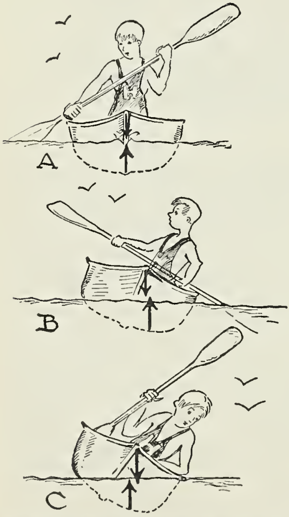
If a toy boat made of tinfoil floats, why will the same tinfoil sink if compressed into a small ball? Is there any difference in the weight of the two masses of tinfoil? If not, how do you account for the fact that the boat floats while the mass of tinfoil sinks? What do we mean by displacement?

---

[1] Buoyancy (bo͞o′yăn-sĭ). Upward force exerted upon an immersed or floating body by a liquid or a gas.

Substances	Density	Relative Density	Substances	Density	Relative Density
	Pounds per Cubic Foot	Specific Gravity		Pounds per Cubic Foot	Specific Gravity
Water	62.4	1.	Glass	162	2.6
Cork	15.6	.25	Aluminum	166	2.65
Cedar	25.	.4	Iron	469	7.5
Pine	31.	.5	Lead	706	11.3
Oak	50.	.8	Gold	1206	19.3

water displaced gives a lifting power equal to 62.4 pounds. Shipbuilders, knowing the densities of different materials and the form of ship to be built, can calculate quite easily its "displacement," that is, how much water it will take the place of. It is evident by a glance at the diagram that the reason ships float is because the materials denser than water are so used that large air spaces are left, and since air is lighter than water, the boat is held up. The table above shows the densities of some common substances.



The lower arrow represents the force of buoyancy, the upper the force of gravity. Explain conditions in *A*, *B*, and *C*.

Stability. We all know the danger of being careless in a canoe or a narrow rowboat, for if we go too far on one side and raise the body too high above the surface of the water, we may suddenly upset. The reason for this is that we have changed the positions of both the *center of gravity* and the *center of buoyancy*. The center of gravity of a body is a point in that body about which the entire mass seems to be centered. The center of buoyancy is the center of mass of that part of a body which is below the water line or it is the center of the space from which water is displaced.

Galloway

Logs collected in a lake above a sawmill. Trace their progress from the forest to this point.

When a person sits close to one side of a boat, that side sinks deeper into the water and the center of buoyancy is shifted toward that side. The center of gravity of the person and of the boat also moves toward the side. If the new center of gravity is between the new center of buoyancy and the keel, the boat will become stable, but if it is between the center of buoyancy and the side, it will upset. A high center of gravity will cause an upset quicker than a low center of gravity. Why? Builders sometimes keep the center of gravity low in boats by adding keels weighted with lead or a heavy load of ballast or tanks of water close to the bottom of the boat are used.

Running Water Is a Carrier of Loads. In many parts of the country running water is used to transport logs to the mills, either for pulp making, for lumber, or for spools and other products. Many trees are cut in the logging camps in winter, and as the streams become swollen from melting snow in the spring, logs by the thousand are rolled into the streams. Sometimes log rafts are made and transported long distances bound together. This method of transportation depends upon the buoyant force of the water and the low density of the floating loads. Water is a carrier of soil which makes land. Dredges are used to deepen water channels to aid shipping. Sometimes the mud dug up is pumped with water through long pipes and discharged near the shore, where the mud thus carried soon builds up above water level, and land "made" in this way is frequently of great value. Parts of many cities are built upon land recovered from the water. Running water is used in many industries to carry materials. In paper-making, it would be difficult to spread the pulp evenly in thin layers for making the paper without the use of running water. You will also recall how running water carries off the loads of waste from our homes in the sewage system.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

gravitation
horizontal
Aristotle
displaces
6.24
line
density
water
vertical
62.4
volume
center
gravity
624
6240
Archimedes
displaced
buoyant
weight
size

As far as we know (1)____ was the first man to understand the (2)____ force of water. Any object immersed in (3)____ loses in (4)____ as much as the weight of the (5)____ water. The density of water is (6)____ pounds per cubic foot, therefore a boat which (7)____ 10 cubic feet of water can hold up a total weight (boat and all) of (8)____ pounds. In order to be stable the center of (9)____ of the floating body and the (10)____ of buoyancy of the displaced water must be in a (11)____ (12)____.

PROBLEM TEST

Mark off on a sheet of paper ten numbered spaces $\overline{1}$ $\overline{2}$ $\overline{3}$ $\overline{4}$ $\overline{5}$ $\overline{6}$ $\overline{7}$ $\overline{8}$ $\overline{9}$ $\overline{10}$ . . . *Place letters in these spaces as directed.*

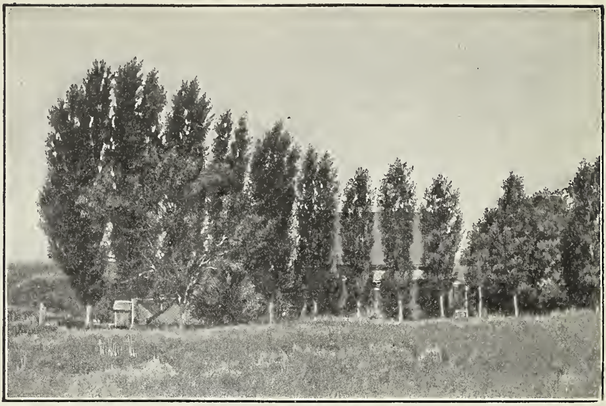
1. If lead is denser than gold, put GO in 4–5, but if gold is denser than water, put the first two letters of density in 3–4.

2. If a floating body displaces its own volume of water, place Y in 1, but if it does not, place CR in 8–9.
3. If the center of buoyancy is the center of the space from which water is displaced, put MI in 5–6. Otherwise put MI in 6–5.
4. If a person has a lower center of gravity when standing than when sitting, remove IM, but if the reverse is true, put SE in 1–2.
5. If some metals denser than water can be made to float on water, put H in 7. If not, put Y in 10.
6. If the keel of a boat makes it more stable, put A in 10. If not, put Y in 10.
7. If a loaded boat with high center of gravity upsets more easily than one with low center of gravity, reverse all letters from 10 to 1. If not, you will miss finding the name of a great scientist.

PROBLEM IV. WHAT RELATION EXISTS BETWEEN RAINFALL AND FOOD PRODUCTION?

The World Is Dependent upon Water for Its Food Supply. If you chanced to visit the market some morning, you doubtless saw stalls full of fresh vegetables and fruits. Others displayed meats and fish, while in the grocery store you may have seen nuts, cereals, and many eatables displayed. Have you ever stopped to think how dependent each one of these articles is upon water? The vegetables, farm crops, and trees which bear nuts and fruits send their roots down deep in the soil after water, and the cattle and the fish which furnish food in their turn depend on the water supply. Everything we buy in the market seems to have required water.

Plant Life Dependent on Water. Anyone taking such a trip cannot help but be impressed with the relation of plant life to water supply. While light and favorable temperatures are necessary factors for the growth of plants, yet water plays an equally important part in their lives. It is very easy to prove that plants seek water. An experiment with a "pocket garden" or with a moistened sponge shows that roots grow toward the source of moisture. If you plant bird seed or mustard seed on the under side of a moist sponge and suspend the sponge by a string, you will find that the roots of the young plants, instead of being pulled downward by gravity, grow upward against it. Examination of the roots of trees and of some large plants shows that they may



Effect of water supply on trees. All these trees are of the same age. Why are those at the left the tallest? An irrigation ditch runs just left of the trees.

grow many feet out of their normal course in search of this life-giving fluid.

Demonstration 6. To Show the Effect of Lack of Water on a Plant.

Take two single plants (beans or other common food plant) in separate pots. Water one of the plants regularly. Let the other go without water. What eventually happens to one of the plants? Allow to remain 24 hours after wilting is first noticed. Then try to restore by watering.

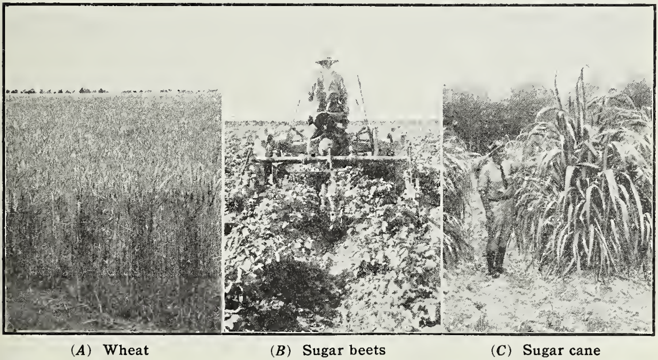
What practical bearing do the truths learned from this experiment have on our production of food?

Rainfall an Important Factor. Rainfall as well as the amount of sunshine plays an important part in the agricultural life of the nation.

If we were to take a trip across the continent, we could not fail to notice the great difference in crops in the various sections. In the Far West and South we have tropical fruits and fiber plants. Many of these tropical fruits are grown in dry regions under irrigation. We have apples in Oregon and New York; sugar beets in eastern Colorado; cotton and sugar cane in the South; wheat and corn in the great Northwest. Differences in climate as well as differences in water supply are responsible for the various kinds of crops. Wheat, for example, needs a cool, moist growing season and a warm ripening season. Corn needs a longer and a warmer growing season than wheat, but is very dependent on water. Oats, barley, and rye take a damp and cool climate. Rice requires much water and thrives best in a warm, wet climate. Grass, the most important food for all our animals, seems to do well with a moderate water supply. Sugar cane requires a deep, moist, and well-drained soil, and a long hot season, while the sugar beet grows in a cooler climate and requires much less water.

Snow in Relation to Crops. Snow plays an important part in the growth of plants. Packed on the sides of mountains, it forms an important source of water, especially in the mountains of the West, supplying water during hot and dry summers to the fields below. In winter it covers fields and gardens with a blanket of insulating material, thus protecting the seeds in the ground from great changes in temperature.

Reclamation of Swamp Land. Some of the richest land in the country is under water. The United States Reclamation Service estimates that there are almost 1,000,000 acres of undrained swamp land in the United States which can be made available for farming when needed. Many thousands of acres of land are yearly being added to the soil of the country, which, because of the decayed organic material in it, is immensely rich. In the Everglades of

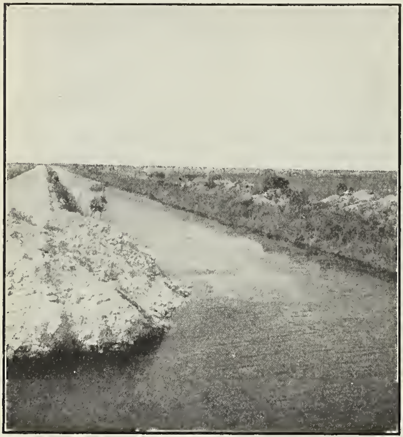


(*A*) Wheat (*B*) Sugar beets (*C*) Sugar cane

Three types of crops, each dependent on a different amount of water. Which needs the most? the least?

Florida, parts of which have already been drained, some of the great drainage canals serve as a means of water transportation, while roads are built along the sides of the canals on the excavated material.

A huge dike 270 feet wide and 20 miles long has just been completed that will eventually add 550,000 acres of fertile land to the kingdom of the Netherlands. Part of the area back of the dike will be drained, the remainder forming a fresh-water lake.



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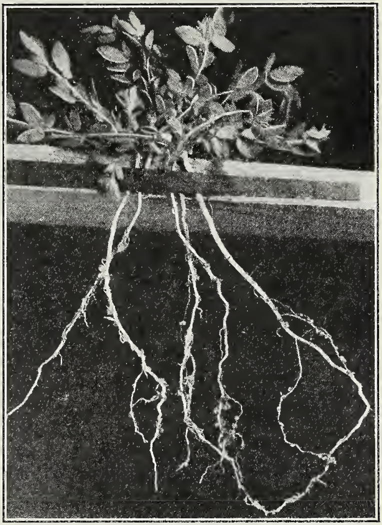
By means of this drainage canal in the Everglades, Florida, much new land is being made available for agriculture.

Dry Farming. A study of the rainfall map on page 77 shows that a good deal of our western country does not get enough rain to support crops. Rain that falls is soon lost by evaporation. In order to overcome this difficulty, farmers practice dry farming. To do this, they first plow the ground deep so that when rain comes, the ground will soak the water up and keep it. Then the surface land is constantly worked over so as to form a thin surface mulch of finely pulverized soil. By plowing and loosening the soil into little particles, water cannot pass so rapidly to the surface and so is kept longer in the soil.

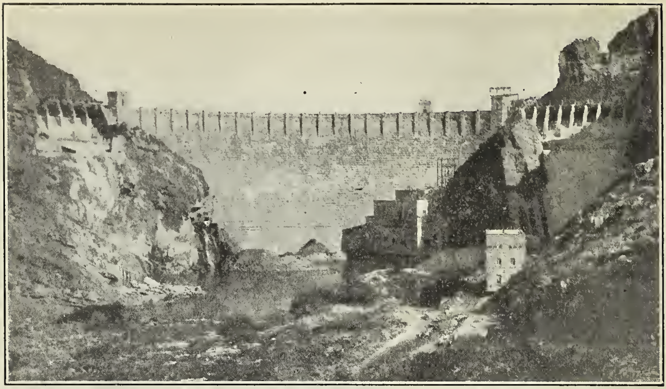
In such regions crops are grown which require little moisture. Alfalfa, which has long roots, reaches the deep-lying ground water and adds to the soil fertility by means of its nitrogen-fixing bacteria. Hard wheat, Kafir corn, millet, and other crops may be grown. In some places farmers can grow only one crop every other year because of the small amount of water available. In such places the farmer keeps half of his land under cultivation and the other half covered with a surface mulch so as to allow water to accumulate.

Irrigation and Irrigation Projects. Irrigation, or the bringing of water from places where it is plentiful to places where there is little water, has been practiced since ancient times. The valley of the Nile in the time of Moses was an irrigated country. In the West there is much rich desert soil which is valuable as soon as water is brought to it. The first private irrigation canals were built in Utah by the Mormons prior to 1912. At that time the United States Irrigation Service was organized, thanks to the farsightedness of Theodore Roosevelt. A study of the map on page 413 gives some idea of the projects that are now complete. Over 11,000,000 acres of land have been thus given water. Each year new lands are opened. Great dams have been built which will hold water and melting snow for use during the hot dry months, allowing it to be sent to areas sometimes, as in the case of the North Platte project, over 150 miles away from the source of the water. As a result of irrigation, land becomes worth from $50 to $300 or more an acre. Great crops of wheat are raised. Potatoes, onions, cabbages, and garden truck of all kinds are grown. Alfalfa and grasses are raised in great abundance. Wonderful orchards have come into existence, oranges and lemons in California, and apples in Oregon. Because of the intensive farming practiced, people live closer together and have all the comforts of community life. The region south and east of Los Angeles in California has become



Wright Pierce

The alfalfa has long roots which strike deep after water. Where could such a plant be cultivated?



Wright Pierce

The Roosevelt Dam has had no water flow over it for several years owing to a succession of dry winters. Most of the water stored here comes from snow which supplies streams which flow into the lake back of the dam.

such an area, due to the use of water which comes down from the mountains which lie to the east. One writer estimates that most of the water that flows in the Santa Ana River, one of the streams which is used for irrigation in this area, is used eight times before it reaches the ocean. The water is first used at the base of the mountains to develop power. Then it is used by the towns of Redlands and Highlands and Riverside both for domestic water supply and irrigation. Then much of this water is recovered by means of wells and used by San Bernardino, Colton, and Riverside. The river bed, which is dry most of the time, again contains some water at the Riverside narrows, where the river runs between rocky hills, and this water is diverted and used for irrigating citrus groves. Finally some of this water is recovered by wells for the city of Santa Ana and the country below. It is doubtful if any of the water reaches the ocean except in time of flood.

Some Irrigation Projects. The Roosevelt Dam and the Granite Reef diversion dam with other smaller dams on the Salt River form a series of lakes over 60 miles long and supply water for irrigating more than 250,000 acres of farm lands which produce fruit, vegetables, alfalfa, and cotton. The Arizona-Yuma project in Southern California irrigates some 65,000 acres of bottom lands

Gabriel Moulin

Irrigation in Washington. What are the furrows running parallel to the canal used for?

Wright Pierce

A fruit ranch in the California desert. Water is obtained from deep wells, and is pumped by windmills to the surface, where it is distributed by irrigation ditches.

in a semitropical desert. In Colorado the Uncompahgre project is interesting because of a six-mile tunnel under the mountains which diverts water from the Gunnison River into the Uncompahgre Valley, where over 100,000 acres of land is made useful for farming. The project has about 550 miles of main and lateral canals already constructed. The great Arrowrock Dam, near Boise in Idaho, will supply water to 275,000 acres of otherwise worthless land. All together there are some 28 projects which will irrigate over 3,000,000 acres of land.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

reclamation
insulation
irrigation
dry
soil
hills
far
life
pure
roots
springs
crops
distant
enough
supply
bought
swamps
brought
grown
largest
usually
water
fertile
lack

The (1)____ of plants depends upon (2)____. If there is not (3)____ rainfall where the plants are (4)____, it may be (5)____ from a (6)____ supply. The presence or absence of a water (7)____ makes the country arid or (8)____. In some parts of the South too much water exists, resulting in many (9)____, while in the West we have great desert areas caused by (10)____ of (11)____. Desert (12)____ usually has all the necessary materials for plant (13)____ except water, so this can be supplied by (14)____. Some of the (15)____ (16)____ in this country come from irrigated lands.

PROBLEM TEST

Write on a piece of paper PLANTS NEED. *Number by placing figures under each letter. Change letters as directed below.*

1. If Florida is a wheat state and Minnesota a cotton state, replace P with F and D with M. If neither statement is true, put an R in place of P and also in place of #4N.
2. If sugar cane and sugar beets do not grow their best in the same locality, put an I in place of each of these letters, L, A, and #7N, but if they do, then put OO in place of EE.

3. If in dry farming farmers grow plants which require no water, put O in place of D, but if the plants do need water, replace #8E with T and #9E with N.

4. If swamp land is rich land, substitute A for #5T, but if it is not, put R in place #1.

5. If there is much rich land where there is insufficient water for crops, put O in place of D; if there is not, put T in #10.

6. If great dams have been built to store water to water food plants in the dry season, put G in place of S; if not, put S in place of #7.

7. If irrigation is a means of draining swamps, omit letters in places #1, #4, and #8; if it is a means of supplying water to dry lands, let every odd letter exchange place with the following even number.

◆

REVIEW SUMMARY

It is important to give considerable thought to the organization of material in your outline. The generalizations suggested do not always make the best general headings for developing the outline, so think over various possibilities before making your final decision.

1. The solvent power of water has important applications in nature, industry, and science.
2. The work water can do depends upon the amount of fall.
3. Water is practically incompressible and so can transmit pressure without loss.
4. The buoyant force of water is fundamental to water transportation.
5. Food plants must be supplied with water.

Check over the survey questions and the various tests in this unit, especially parts you feel doubtful of. Make your outline, filling out details rather fully. Keep this outline in your workbook where it will be ready for any report you may be called upon to give.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × 2½.*

I. **The ability of water to dissolve substances is a disadvantage because it:** (1) removes plant food from the soil; (2) produces hard water; (3) has produced salt water in the ocean; (4) promotes chemical changes; (5) helps wear away rocks.

II. **Crystals separate from a saturated water solution of sodium carbonate when:** (6) it is heated; (7) ice cold water is added to it; (8) it is allowed to evaporate at room temperature; (9) when it is corked tightly in a bottle to prevent evaporation and is cooled to a low temperature; (10) more crystals are added.

III. **When water flows down a penstock to a water turbine, the energy it can deliver depends upon the:** (11) length of the penstock; (12) vertical height of the water in the dam above the turbine; (13) temperature of the water; (14) amount of water back of the dam; (15) rate of flow.

IV. **Hydroelectric power refers to:** (16) the use of water for making steam to run a steam engine which in turn operates a generator which makes electricity; (17) using electric power to pump water; (18) making electricity by using hydrocarbon fuels; (19) generating electricity by using falling water; (20) the production of hydrogen from water by using electricity.

V. **The hydraulic press makes use of these facts:** (21) compressed air exerts greater force; (22) water is incompressible; (23) confined water transmits pressure without loss; (24) the pressure from the piston where effort is applied is communicated to the piston where resistance is overcome; (25) water has high density.

VI. **The buoyant force of water equals:** (26) the volume of a floating body; (27) the weight of a body immersed in water; (28) the weight of the water displaced; (29) the weight of a floating body; (30) the loss in weight of a body weighed in water.

VII. **In many arid regions the soil is rich because:** (31) water has not dissolved and carried off the plant foods; (32) few plants are there to use up the plant foods; (33) it is sparsely settled; (34) of the action of the hot sun on the soil ingredients; (35) of the large amount of decaying animal and vegetable matter in it.

VIII. **When running water is turning the wheels in a mill, it is:** (36) using energy derived from the earth; (37) using energy derived from the sun; (38) using kinetic energy; (39) gaining potential energy from falling; (40) losing energy.

PRACTICAL PROBLEMS

1. A boy has built a raft of 6″ × 6″ square timbers fastened closely together. It has four hollow barrels securely held, one under each corner. The raft is 6′ × 8′ in area, and without a load the surface stands a half a foot above the surface of the water. Can this raft be used safely in smooth calm water to transport a load of eight boys, whose average weight is 125 pounds? How great a load can it support without sinking below the surface of the water?

2. A man claims to have a large nugget of gold and as he "needs the money," offers to sell it to your father for a small price. How can you determine if it is real gold?

3. Two boys are building boats, one a rowboat and the other a sailboat. One of the boys uses a deep, heavy keel on his boat. What is its purpose and how does it work?

4. How is a life preserver put on? How could you make a laboratory test to see how much a given life preserver will support in water?

5. Does a life preserver need to support the entire weight of a person? Explain.

6. A piece of sheet lead is eleven times as dense as water. How can you make it float in water without the use of other light objects?

INTERESTING THINGS TO READ ABOUT

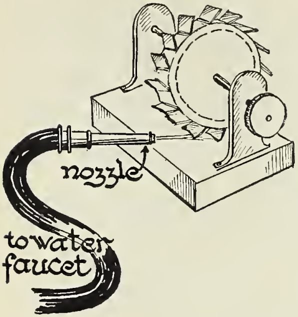
1. Irrigation from the Nile.
2. Reclaimed land in Holland.
3. Swamp drainage in the United States.
4. Progress on the Boulder Dam.
5. An important chemical industry.
6. The drought of 1934.
7. Enormous pressure from the hydraulic press.
8. Floating docks.
9. World's largest sources of water power.
10. Work of the industrial chemist.

LEISURE TIME ACTIVITIES

1. **A crystal collection.** Collect good crystals of salts for your museum. You can make a good cabinet from a cigar box to hold them. Remove all paper, put in partitions, shellac the surface. Place a glass over the top. Some crystals you may get are: copper sulphate (blue), potassium dichromate (red), potassium permanganate (purple), iron sulphate (green), alum (white). Never taste any crystals as they may be deadly poisons.

2. **A crystal garden.** Fasten some cloth over irregularly shaped rocks and place in a saucer or soup plate. Make a saturated solution of ammonium chloride. Pour this over the cloth. Use enough to make a pool in the bottom of the dish. As the water evaporates from the cloth, crystals form. More liquid creeps up the cloth, enlarging the crystals. Colored crystals may be dissolved in parts of the garden. Mercurochrome, red ink, bluing, or dyes may be used to add variety and color effects.

3. **Make a water wheel.** If you are good at manual work, you can devise a water wheel so that a jet of water playing upon the blades will make it revolve.



4. **Work of water.** Make a scrapbook of articles and pictures dealing with the work water can do.

SCIENCE CLUB ACTIVITIES

1. **Excursion to a chemical industry.** If there is a large soap factory near, it will be an interesting place to visit.

2. **Stability of a boat.** Have someone bring a small model boat. Fill a tub with water. Have a piece of 1″ or 2″ lead pipe 4″ to 8″ long; the size needed depends upon the size of the boat. Try different positions of the lead pipe, say middle, side, bow, and stern. Use the lead lying flat and standing on end. Observe carefully the result on the tipping of the boat. If you can get a boat with detachable keel, try it both with and without the keel while varying the position of the load.

3. **Irrigation.** Send to Bureau of Reclamation, U. S. Department of the Interior, Washington, D. C., for printed matter on *Federal Irrigation Projects.* This gives material for a number of interesting reports.

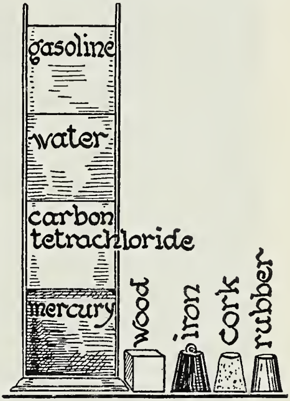
4. **Terms related to solution.** There are many terms which are not exactly understood by the average person. Have these looked up and reported upon. Possibly someone may run across a good demonstration to illustrate some of the terms. Here is a list to start you off.

soluble
solute
solvent
solution
emulsion
tincture
suspension
precipitate
insoluble
extract
colloid
crystalline
amorphous
saturated solution
supersaturated solution
osmosis

5. **A fast-growing chemical garden.** Prepare a solution of sodium silicate: 1 part sodium silicate to 3 parts water. Filter if not perfectly clear. Pour this into a tall but small vessel with clear glass walls. Procure very small crystals of various salts, for example: copper sulphate, iron sulphate, nickel sulphate, cobalt nitrate, calcium nitrate, and cadmium nitrate. Drop a few of these crystals into the solution

and watch the "chemical plants" grow. Read up on osmosis to understand the action. The salt dissolves in the water. Then it combines with the sodium silicate, forming a shell of insoluble metallic silicate. This shell is slightly porous and water enters the porous tube faster than the solution of the salt inside can pass out. This creates pressure which ruptures the shell at the top where it is the thinnest. The two solutions come together again and the chemical action builds the shell higher. This action is continued and gives the appearance of the growth of plants.

5. **How a body which sinks can float at the same time.** Add four different liquids to a tall glass cylinder. Each should measure about 3″ in depth. Incline the cylinder and pour each slowly down the side in this order: mercury, carbon tetrachloride, water, and petroleum ether or gasoline. Can you predict what will happen when you drop four solids, oak wood, iron, cork, and rubber, into the cylinder? Some rubber stoppers have a relative density slightly less than one and some a little more than one. Use the denser one for this experiment. Trial will show if you answered the above question correctly.



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Survey Questions

Where does our heat come from?
Do you know where and how our natural fuels were formed?
How are artificial fuels made?
Can you read a gas meter?
How can steam run engines?
Do you know how gasoline can give motion to an automobile?
Do you know the difference between a Diesel engine and an automobile engine?
How is heat used in industries?
Do you know how steel is made?

R. I. Nesmith and Associates

UNIT V

THE HEAT-USING WORLD

PREVIEW

Have you ever thought of what the world would be without heat? Life would be impossible. Even if the sun's heat were but slightly reduced, huge glaciers would soon form and all living things would perish. The sun is the source of all energy, and therefore of all heat. It seems queer to think of the glaciers of our present day being due to this same sun, but remember that the sun causes the evaporation of water which forms clouds, and that glaciers come from snow. Remember also that our water cycle is due to the energy of the sun. Water power is indirectly sun energy. When we come to fuels, here remember that the sun must have made the great supply of coal, oil, and natural gas now locked in under the earth's surface from once-living plants and animals. In this way the energy that man converts by his machines came from the sun. This unit will help us to understand a little more about this transformation of energy.

We are blessed with a great abundance of natural resources: coal, gas, oil, water power, and various ores, all kinds of raw materials. Waterways and railways have helped to make our prosperity greater. The United States furnished in 1933 more than 350,000,000 tons of coal, or about one third of the world's supply, and nearly 900,000,000 42-gallon barrels of oil, the total world production being only 1,417,520,000 barrels. No wonder we have prospered more than other nations.

With the development of the steam and gas engines the use of our natural fuels has increased by leaps and bounds. A comparatively few years ago all work was done by men and horses or other beasts of burden. Today in thousands of communities hundreds of thousands of machines are at work. No wonder we call this an age of machines.

In order to understand fully the value of the earth's heat-producing substances and their uses as fuels, it is essential that you understand certain fundamental principles and important facts relating to heat before you study this unit. Test yourself to see if you are ready to profit to the fullest extent in this study by seeing to it at the start that you understand the following:

1. In ordinary combustion oxygen combines with some element, producing light and heat.
2. Matter exists as a solid, liquid, or a gas, depending upon the quantity of heat energy it holds.
3. Different substances have different boiling points.
4. Heat may produce a change in (*a*) temperature, (*b*) size, (*c*) state, (*d*) chemical composition, (*e*) kind of energy.

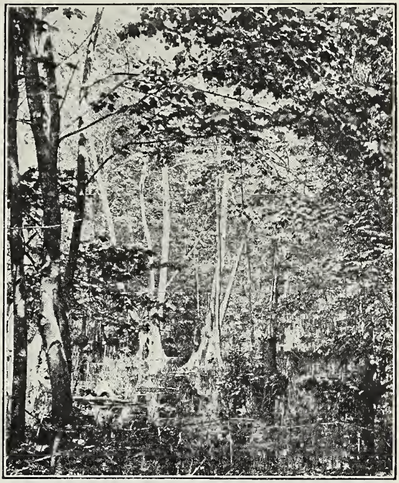
PROBLEM I. WHAT IS THE SOURCE OF HEAT ON THE EARTH?

We have already seen that the sun is the source of practically all our energy. We know that agriculture depends upon its rays; we know that all living things depend upon the food made by green plants; and we also know that the sun's energy in past ages has formed great storehouses of fuels under the ground.

Heat Stored in the Earth. There is an enormous amount of heat stored deep within the earth. Volcanoes and hot springs give evidence of this. In few places, however, has any practical use of this heat been made.

Common Fuels. Wood for many years was the most important fuel and it still has an excessive use. Its value as a fuel lies in the fact that it is composed chiefly of hydrogen and carbon. These elements have been combined in the leaves of plants. Fuels yield heat when they burn, that is, when they combine with oxygen. Coal, oil, gas, and gasoline are the most important industrial fuels today.

How Coal Was Formed. Some millions of years ago there were vast areas of swamps bordering an inland sea. The nearest examples of these which exist today are the Great Dismal Swamp in Virginia and North Carolina, the Everglades of Florida, and the delta regions of the Mississippi River. The vegetation in these ancient swamps was very dense and consisted of shrubs, mosses, and many fern-like trees. Slow sinking of the land allowed continued growth and long resting periods between periods of sinking made it possible for large accumulations of vegetable matter there. Then more abrupt changes carried this bed of vegetable matter under water so that running water could cover it with layers of sand or clay. Sometimes it was covered by a deposit of shells which eventually changed to limestone. In places many layers of vegetable matter were produced, separated by many layers of earth deposits. When the vegetable material was very deep in the earth, it was greatly compressed by the weight of the overlying layers. Under the combined action of heat and pressure much gaseous material was given off until at length it left a hard, black, mineral-like substance having a high per cent of carbon. This is the coal of today. The seams of coal now found in the earth are only about 7 per cent of the volume of the original mass of vegetable matter from which they were made.



Society for Visual Education

The Great Dismal Swamp. How is this area like those in which coal was formed?

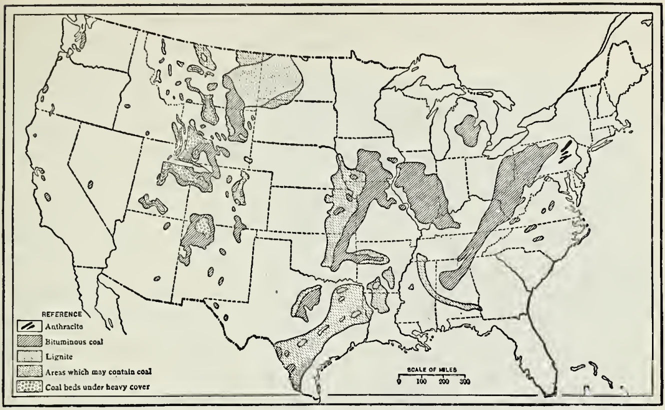
Peat. There are fresh-water peat bogs in many parts of the world today. Sphagnum moss will grow floating on the surface of water. The old plant under water dies and sinks. This produces a vegetable muck rich in carbon. An entire pond may be filled in this way. This partly decayed vegetable matter called *peat* is sometimes cut into blocks, dried, and used for fuel. Some ancient bogs were covered by sediments and coal was formed from the peat in them. Peat is the first stage in the changes which eventually produce coal.

Kinds of Coal. Coal differs from peat in being much more compact and harder. It represents later stages of development. There are three important varieties of coal which represent different stages in this natural process of change. Lignite or brown coal is the first product. Bituminous coal comes next, and the final stage is anthracite. Bituminous or "soft coal" has much gaseous material left in it and burns with a smoky flame. Anthracite or "hard coal" has less gaseous material left in it, and burns with less smoke and is therefore relatively clean fuel.

Value of Coal Determined by Tests. You cannot tell much about the fuel value of coal by just looking at it. It may have very much rock material which will not burn. We buy coal and depend upon the coal dealer to give us a good quality. Large users of coal, however, buy coal on *specification;* that is, it must give a certain amount of heat per pound. They must know if it burns clean or is smoky, how much ash it produces, and if the ash

Publishers' Photo Service

A modern coal mine. Can you name several things shown here that were not used in mines fifty years ago?



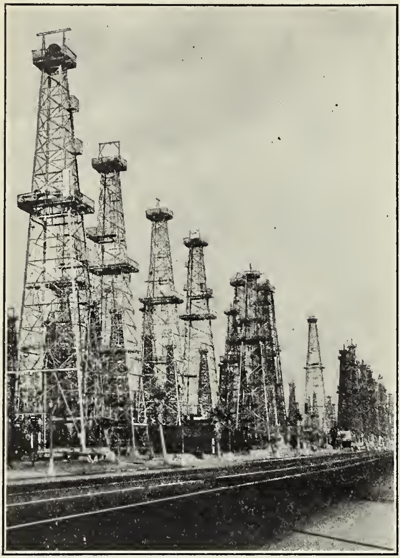
U. S. Geol. Survey

Study the map carefully and make a list of states in which the most coal is found and what varieties are found in the different states.

is fine grained or makes large clinkers. Many manufacturers have their own chemical laboratories and test each shipment of coal. The amount of heat is determined in a device called a fuel calorimeter. A good grade of anthracite coal will give 13,000 heat units per pound. One heat unit is the heat required to warm 1 pound of water 1° F. From this you can quite easily see that one pound of good hard coal should give enough heat to warm 100 pounds of water to 130° F. Coal has much heat stored in it, but our heating devices are unable to make use of all of it. Much heat is lost.

Distribution of Coal. Coal is found all over the world except in the tropics. Great Britain, Germany, and many other parts of Europe have used large amounts of their coal, but China, which has great coal beds, has scarcely touched her great deposits.

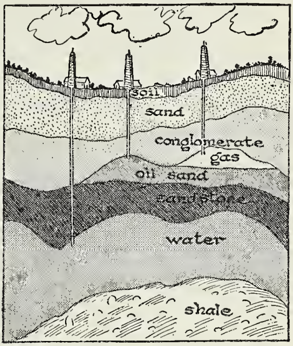
Petroleum. Petroleum, or oil, is another fuel which probably comes from the decay of plants and animals whose substance was formed through the aid of the sun's energy. There are some who think the oil came from inorganic chemical action within the earth. But whatever its source, petroleum or crude oil is held in great pools in some porous layers under the ground, and is obtained by drilling wells. The oil in most cases is held near the crest of a fold in an impervious layer. When this is tapped, the oil spurts out as water does from an artesian well. The greatest oil-producing fields are those of Texas, California, and Oklahoma, in the order named, while smaller amounts of oil come from Kansas, Louisiana, Wyoming, Arkansas, and several of the Eastern states. It was not until 1859 that the first oil well was drilled in this country and oil came into general use, first for lighting and, with the coming of the automobile, for power. It is estimated that at the present time in this country we take out of the earth seven barrels of oil per person a year. The use of oil for fuel is rapidly increasing. Steamships, especially battleships, burn oil, and many railroads have equipped their engines with oil burners, especially in regions where oil is abundant. In some parts of the country factories are run entirely on oil. Particularly is this true in California, where coal is lacking. The by-products of petroleum are also valuable as lubricants, most of our machine and motor oil coming from this source.



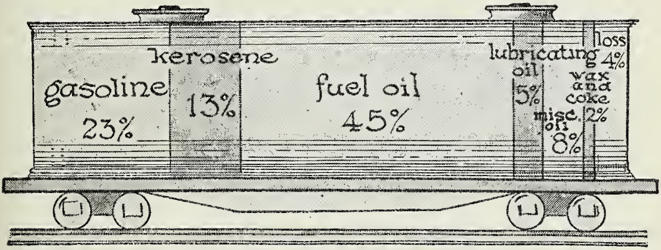
Wright Pierce

An oil field in southern California. Notice two types of derricks. Why do you think the wells are sunk in lines?

Gasoline. Petroleum as it is taken from the ground is a mixture of many compounds — all composed of carbon and hydrogen. These include gasoline, kerosene, fuel oil, and lubricating oils. At one time kerosene oil was the most valued derivative from petroleum, but with the tremendous increase of motor cars, gasoline is now the most desired product. The compounds in crude oil have different boiling points. Advantage is taken of this in separating them. Petroleum refining is the most efficient organization of any industry. There is no waste in separating the different products by distillation and no product is without a use. In oil refineries you find complicated stills which separate the different compounds by a process called *fractional distillation.* Gasoline, having a lower boiling point than kerosene, comes off at a lower temperature. Kerosene has a lower boiling point than fuel oil and fuel oil lower than lubricating oils. Thus if we heat crude petroleum gradually, the gasoline comes off first, then kerosene, then fuel oil, and then lubricating oil. After each fraction has been separated by being changed to a gas it is condensed and each fraction run into a special container.



In drilling for oil, gas or water is sometimes obtained. Explain.



Products obtained by fractional distillation and refining from a tank car of crude petroleum. Which are the by-products? Which is the most valuable product?

Cracking Plants. Today not only is the gasoline that is in the petroleum separated, but some of the compounds of higher boiling point are "cracked." That is, they are subjected to a chemical process of high temperature and pressure by means of which they are decomposed into gasoline. Chemists have also found a way of making gasoline from coal and from water gas. It is also separated from natural gas.

Why Gasoline Is a Greater Fire Hazard than Fuel Oil. Gasoline is a very volatile liquid whose mixture with air is extremely explosive. This is very useful in the automobile, but is a great hazard in the garage or in the home, where a spark may come in contact with gasoline vapor and air, thus causing an explosion.

Demonstration 1. To Show the Flash Point of a Volatile Liquid.

(*To be done only by the instructor. Have a large wet towel at hand if needed to smother the flames.*)

1. *Fuel Oil.* Fill a tablespoon three fourths full of fuel oil. Attach a glass jet tube to a flexible rubber tube and connect to the gas outlet. Produce a very small gas flame at the end of the tube. Pass this flame quickly over the surface of the fuel oil. If there is no flash of flame produced above the liquid, remove the test flame and heat the oil with a very small Bunsen flame. Make tests occasionally while heating to see if a flash occurs.
2. *Kerosene Oil.* Test kerosene in the same way. Does it require as long heating to produce the flash as it did for the fuel oil?
3. *Gasoline.* Fill a tablespoon only one fourth full of gasoline. Bring the test flame near the surface. If the gasoline continues to burn, smother it.
4. *Alcohol.* Test alcohol in the same way as gasoline.

All of the four liquids mentioned in the demonstration evaporate if left in the open air. Their vapors mixed with a sufficient amount of air are explosive. Heat increases the rate of evaporation. Fuel oil and kerosene evaporate so slowly that unless in an enclosed space the amount of the oil is too small to explode, but when heated, an explosive mixture will result. At a temperature a little above the flash point the vapor may be given off so rapidly that the liquid will continue to burn. This occurs at the burning temperature. The ordinary air temperature is above the burning temperature of gasoline and alcohol and is much above the flash point of these liquids. It is because gasoline has such a low flash and burning temperature that it is so dangerous to bring a lighted match or cigarette near it or even to produce a spark. Its vapor mixed with air may be carried some distance from the liquid, and if ignited, the flame travels with explosive violence to the gasoline which is the source of the vapor.

Natural Gas. The production of natural gas in this country in 1933 was estimated at 848,652,300,000 cubic feet, having a value of over $300,000,000. Natural gas is associated with oil in pools and comes to the surface under enormous pressure. In the past much gas has been wasted. With the discovery of its value as a fuel, and because of the ease with which it is obtained, it has been found possible to make great pipe lines through which it is delivered to cities where it will be used. Such pipe lines, measuring hundreds of miles in length, are found in California, while one has just been completed which brings gas from the Oklahoma fields to Chicago. At the present time there are more than 160,000 miles of gas and oil pipe lines in existence.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

earth
fire
water
air
carbon
oxygen
health
wealth
minerals
vegetation
raised
black
gas
buried
peat
changed
petroleum
gasoline
conditions
deposits
beds
coal
temperature
pressure

At one time (1)____ was far more luxuriant on the (2)____ than it is today. Enormous (3)____ of vegetable matter collected under (4)____ and were eventually (5)____ deep in the earth. Under (6)____ of very great (7)____ and heat this matter was (8)____ into (9)____ which is (10)____ in color and contains a large amount of (11)____. There are extensive (12)____ of (13)____ and natural (14)____ in the earth which are sources of much of our fuels.

PROBLEM TEST

There are certain facts and principles of science that are responsible for the formation of coal on the earth many years ago. *Select from the following list those which are:*

(1) *Significant,* that is, those which did have some influence in causing the formation of coal.

(2) *Irrelevant,* or those which had no effect on the production of coal.

1. Heat can drive volatile matter from organic compounds.
2. Wood heated above its kindling temperature will not burn if deprived of oxygen.
3. There is an abundance of vegetation on parts of the earth today.
4. Peat is used for fuel in several different countries.
5. There have been periods of land sinking and periods of land elevation.
6. Any material buried deep below the earth's surface is under tremendous pressure.
7. Glaciers carry much earth from one place to another.
8. When plants are cut down or die, they decay.
9. The deeper one goes down into the earth the hotter it gets.
10. Coal beds vary greatly in thickness, some being less than a foot deep and others more than ten feet deep.

PROBLEM II. HOW ARE ARTIFICIAL FUELS MANUFACTURED?

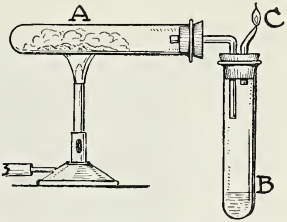
Manufactured Fuels. There are three important manufactured fuels: *charcoal,* derived from wood; *gas,* obtained from soft coal; and *coke,* left as a by-product in the manufacture of gas. Charcoal is made by burning wood in closed kilns or ovens called charcoal pits. Wood is allowed to burn slowly without much oxygen for several days. During this time all volatile matter is passed off, leaving almost pure carbon behind. This is charcoal. Coke is extensively used in the iron industry and is a particularly efficient and clean fuel for household use.

Demonstration 2. How to Make Charcoal.

Heat pieces of wood about 2 inches long and diameter of lead pencil in an iron pan over a hot flame. Have the wood well covered with sand to keep the air away. After 15 to 20 minutes cool and remove the sand. How does the product differ from the original wood?

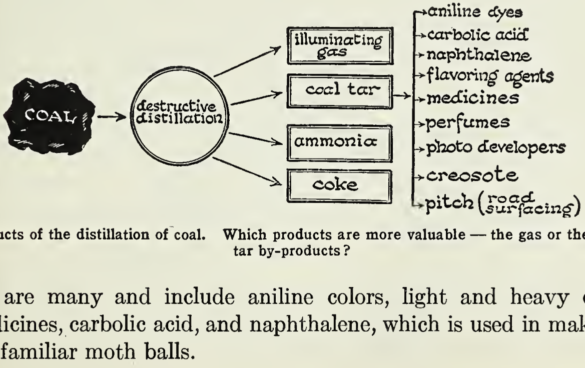
Manufacturing Artificial Gas. Gas for a city community is usually manufactured either by destructive distillation of coal or by what is known as the water-gas method. Both kinds of gas are frequently produced in the same plant and are mixed in the mains for use.

Demonstration 3. Making Coal Gas.



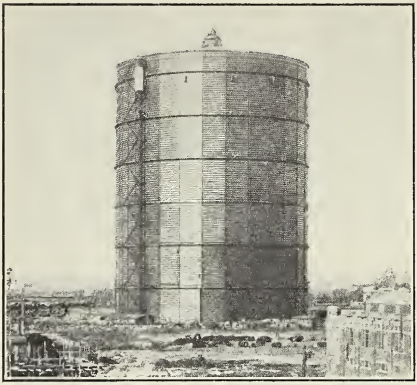
Grind enough soft coal to make about three teaspoonfuls of coarse powder. Fill a hard glass test tube about half full of the powder. Arrange the apparatus as shown in the diagram. Clamp the tube in a nearly horizontal position. Apply heat gradually at first, then very strongly to that part of the tube where the powdered coal is. When the gas is coming off rapidly, apply a flame at the jet tube at *C*. When the tube is cold, get a piece of the solid residue out of the tube. Did you notice any products other than the gas and coke being formed? Describe the liquid found in *B*.

Coal Gas Manufacture. In the process of destructive distillation of coal, the complex substances of the coal are broken up into simpler substances by the heat. Soft coal, which contains from 30 per cent to 40 per cent of volatile matter, is heated in iron retorts. This produces a residue of almost pure carbon called *coke*. Coke burns with a very hot flame, is clean, and is used in many homes as fuel either alone or mixed with coal. In making gas, a ton of coal produces on an average two thirds of a ton of coke, 13 gallons of tar, 20 pounds ammonium sulphate, and 12,000 cubic feet of gas. The products that can be obtained from the coal tar are many and include aniline colors, light and heavy oils, medicines, carbolic acid, and naphthalene, which is used in making the familiar moth balls.


COAL
destructive distillation
illuminating gas
coal tar
ammonia
coke
aniline dyes
carbolic acid
naphthalene
flavoring agents
medicines
perfumes
photo developers
creosote
pitch (road surfacing)

Products of the distillation of coal. Which products are more valuable — the gas or the coal tar by-products?

Steps in the Process of the Manufacture of Coal Gas. Soft coal is placed in the retort over the furnaces in which coke is burned. The gases and by-products pass off into what is known as a hydraulic main. In the hydraulic main some of the tar is condensed and disposed of, still more of it being taken out a little later by what is known as the tar extractor. The gases are then forced through a spray of cold water in condensers and scrubbers by means of which the ammonia and other by-products are removed. The gas then passes through the purifiers, where carbon dioxide and sulphur compounds are removed. It is then measured and passed on to the huge tank or holder, which is a familar blot on the landscape of so many cities. From this holder it is passed out through the city mains and distributed to the homes, where it is used for cooking and other heating purposes.


A city gas holder. Have you seen the new type of holder which holds gas under compression?

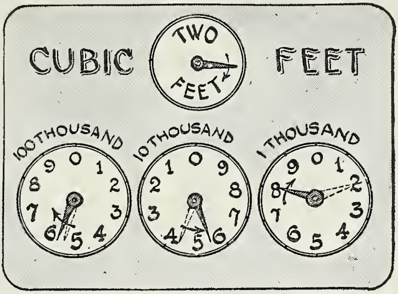
Water Gas. Water gas is made by passing steam under pressure through incandescent hard coal or coke in a generator. The gases pass off into a structure called the *carburetor*. Here coal oil is sprayed into the gas. It then passes to the superheater, where it is changed to a permanent gas. The chemical change that occurs in the generator is expressed by this equation:

$$\begin{array}{ccccccc} C & + & H_2O & = & CO & + & H_2 \\ \text{Coke} & + & \text{Steam} & = & \text{Carbon monoxide} & + & \text{Hydrogen} \\ & & & & \multicolumn{3}{c}{\text{Water gas}} \end{array}$$

Carbon monoxide has small fuel value, and in order to bring water gas up to the heat standard required by state laws it is enriched by the addition of the fuel oil. The permanent gases which are produced from the fuel oil contain both carbon and hydrogen.

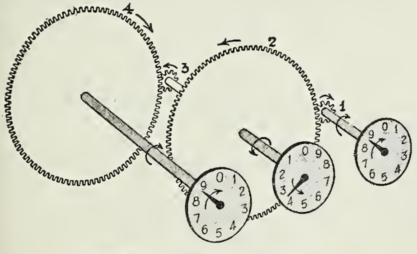
How Gas Is Measured. Gas is commonly sold by the 100 cubic feet or 1000 cubic feet, therefore, all gas which passes into the house must be measured. This is done in a meter which automatically registers on a dial the quantity of gas which goes through it.

Reading the Gas Meter. The recording index of a small gas meter has three dials, and a fourth one, still smaller, on top, which has a scale registering two cubic feet. Above the three dials are marked the figures 100,000, 10,000, and 1000, and the face of each dial is figured from 0 to 9. When the gas passes through the meter, the hands revolve, the two outer ones in the direction of the hands of a clock, and the middle one in the direction opposite. In the illustration the 100,000 dial hand is between 5 and 6, the 10,000 between 5 and 6, and the 1000 at 8. This means that the meter stands at 55,800 cubic feet. The last time the meter was read, as the dotted positions of the hands show, it stood at 54,200.



Calculate the gas consumed in the interval, between the two readings shown in the diagram.

Back of the dial face of the meter are various interlocking gears. Wheel 1 has 10 cogs and wheel 2 has 100. When wheel 1 has turned around once, what part of a revolution has wheel 2 made? How many times must wheel 1 revolve to make wheel 2 revolve once?



Interlocking gears of a gas meter.

The shaft joining the indicator pointer with wheel 1 turns the pointer in a clockwise direction. Will the pointer joined to wheel 2 turn in a clockwise or a counterclockwise direction?

Wheel 3 is on the same shaft as wheel 2. It has ten cogs and engages wheel 4, which has 100 cogs. When 2 and 3 make one complete turn, how far will wheel 4 have gone?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange in proper numerical order. The same word may be used more than once.

methylene
solid
peat
gas
lignite
oil
steam
air
hard
soft
heavy
retorts
coke
naphthalene
destructive
liquid
charcoal
tar
coal
anthracite

By burning wood without much (1)____ (2)____ is produced. They make coal gas by heating soft (3)____ in a process of (4)____ distillation. (5)____ is a product left in the retort. Tar passes out of the gas (6)____ as a (7)____, but by cooling later it becomes a (8)____. Water (9)____ is made from (10)____ or hard coal which is exposed to water in the form of (11)____. One by-product of coal-gas manufacture is (12)____ used in moth balls.

PROBLEM TEST

There are mistakes here. Rearrange the endings to make the sentences read correctly.

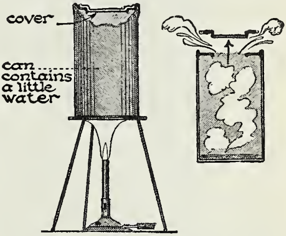
1. The hot gases from the retorts are first cooled	(*a*) in heated iron retorts.
2. Coke is made from coal	(*b*) in the superheater.
3. In making water gas steam is sent over white-hot coke	(*c*) in the carburetor.
4. The oil added to water gas is changed to a permanent gas	(*d*) in the scrubbers.
5. Much of the ammonia is removed from the gas when it is cooled	(*e*) in the gas holder.
6. A mixture of coal gas and water gas is stored	(*f*) in the hydraulic main.
7. Oil to enrich water gas is added when the gas is	(*g*) the generator.

PROBLEM III. HOW DOES HEAT PRODUCE STEAM POWER?

Demonstration 4. How to Develop Power from Steam.

Materials. Tin can with friction cover (quart paint can or Karo can).

Method and Result. Put a cupful of water in the can. Close it tightly with the cover. Place the can over the fire and boil the water. Stand at a distance and continue the boiling until the pressure of the steam manifests itself in a decided manner. How did the compressed steam show its power?



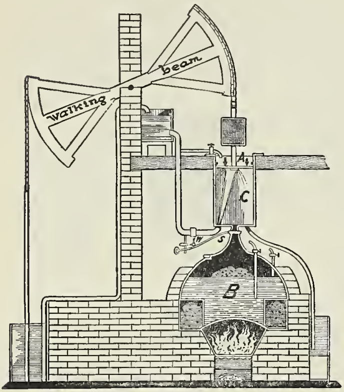
Conclusion and Explanation. What was happening to the steam during boiling? When did the steam expand? What did it do at the moment it started to expand? What caused this result? Do you think steam can be used for power? Explain.

Practical Applications. Motion in the steam engine is produced by compressed steam trying to occupy a larger space.

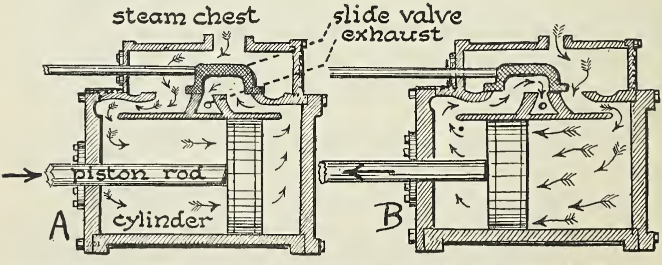
Why Steam Is Used in Engines. Heat changes water into steam, which is a gas. If the steam is not confined, it will be under the same pressure as the air and will spread out until it occupies 1700 times as much space as when it was a liquid. If the steam is not allowed to fill this large space, the energy absorbed and held in the molecule of the steam will then show itself in increasing the pressure. When open to the air, the steam has a pressure of only 15 pounds per square inch, but confined in a boiler it may have several hundred pounds of pressure per square inch. The secret of using steam for doing work lies in first confining it and raising its pressure, then in letting it expand as it passes through engines built for the purpose.

The Development of the Steam Engine. The story of the invention of the steam engine has been the result of the thought of many minds and the combined work of many inventors.

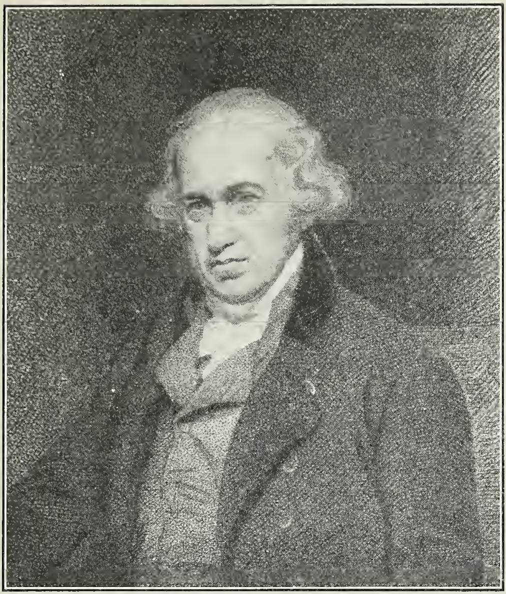
Hero of Alexandria, about one hundred and fifty years before Christ, described a toy in which steam caused a ball to revolve, but it was a great many centuries later that steam was actually put to practical use. Denys Papin, a Frenchman, made the first model of a steam engine using the idea of the piston. In 1698 Savery, an English military engineer, made the first useful engine. In 1705, Newcomen, an English iron worker, completed an improved engine. His engine had a piston which was raised by steam pressure. The steam was condensed in the cylinder *C* by a jet of cold water, thus reducing the pressure. This allowed atmospheric pressure at *A* to push the piston to its original position. The power was transmitted from his engine to the pump by means of a walking beam. This invention came at an opportune time for use in the English coal mines, many of which could not be worked at this time because they were half full of water. James Watt, an inventor and engineer, was called upon to repair a model of Newcomen's engine. He not only repaired the model, which was then in the physics laboratory in the University of Glasgow, but he realized that steam, and therefore motive power, was wasted by the alternate heating and cooling. He began a study which



Newcomen's engine. *A*, piston; *C*, cylinder; *B*, boiler; *S*, steam valve; and *W*, water valve. Explain its operation.



What advantages has the engine using this cylinder over the Newcomen engine? Read your text carefully before you answer.



JAMES WATT, 1736-1819.

JAMES WATT was born in the little town of Greenwich, Scotland. His father was a well-to-do shipbuilder, and the boy, who was delicate, was educated at home. He was early interested in mathematics, and there is a story that one day, when watching the steam lifting the lid of a teakettle, he got his first knowledge of the power of steam. His father early lost most of his money, and young Watt, instead of going to college, went to London to learn a trade. Returning to Glasgow, he became a repair man for the University. While there he chanced to be asked to repair a model of the crude Newcomen engine which was made in 1705. Watt at once saw it was inefficient and kept at it until he found out what the trouble was. The result was that he changed completely the working of the piston so that steam moved the piston up and down instead of in one direction only as in Newcomen's engine. Watt's first engine was far from a suceess, and he lacked money to carry out his ideas, but his first great pumping engine was set up in 1777 and did its work so well in pumping out a mine that Watt's fortunes rose from that very hour.

◆

resulted in a greatly improved engine. Watt soon found that he could modify his engine and use it for other purposes than pumping water. Watt's improvements were these: first, he kept the cylinder hot all the time instead of having it alternately heated and cooled; second, he had steam pushing the piston on both of its strokes instead of one only; third, he regulated the flow of steam to the cylinder so that the steam from the boiler was cut off when the piston had made one fourth of its stroke, which more than doubled the efficiency of the engine, the added work coming from the expansion of the steam; fourth, he used oil for lubrication and to keep the steam from escaping around the working parts.

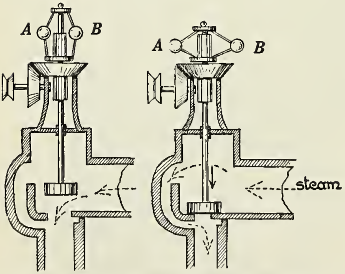
Demonstration 5. How Does a Steam Engine Work?

Materials. Steam engine model.

Method. Turn the flywheel until the slide valve is in position to admit steam first on one side of the piston head and then on the other. Make two diagrams of the cylinder and steam chest to show these two positions of the piston and slide valve. Examine the eccentric to see how it works and explain its purpose.

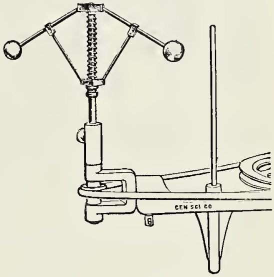
Conclusions. Of what use is the cylinder? The piston rod? The flywheel? The governor? How is energy liberated from steam?

The Steam Engine of Today. The stationary steam engine in use today has some improvements on the one made by Watt. Steam is generated by heating water in the iron tubes of a boiler. Heated gases from the fuel in passing around these pipes turn some of the water into steam. This collects in the upper part of the boiler and is carried by a pipe to the steam chest of the engine. It then passes alternately through two openings into the ends of the cylinder, first on one side of the piston and then on the other. The entrance of steam into the cylinder is controlled by the slide valve, which is moved by an eccentric placed on the shaft of the flywheel of the engine. Steam entering at one end of the cylinder pushes the piston in one direction;



Read your text and then explain the diagram above.

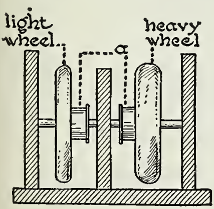
and when entering at the other end, pushes it back again. Two devices give it an even and a regular motion. These are the flywheel and the governor. The flywheel, by its momentum, prevents a slowing up of the engine when the load is suddenly increased. The governor automatically regulates the supply of steam entering the steam chest. This is done by the centrifugal action of the balls of the governor (*A*, *B* in diagram). As the speed at which these balls rotate increases, they swing outward and partly close the steam valve, which causes the engine to slow up a little. Then the balls revolve less rapidly, and more steam is allowed to come in. These two opposing actions soon become adjusted so that an even speed is maintained.



Demonstration 6. To Show Centrifugal Motion

Attach the device having two heavy balls loosely suspended from the top of a vertical spindle, to the rotator. What happens when you increase the speed of rotation? How can a device of this sort be used to regulate the flow of steam into a steam engine?

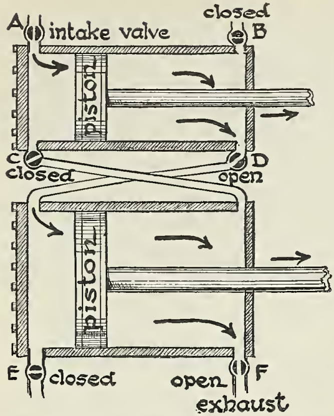
Demonstration 7. Momentum



Materials. Two light wooden wheels ½ inch thick and 5 inches in diameter, supported so they can rotate easily upon fixed bearings. A piece of heavy wire solder long enough to extend around the circumference of one of the wooden wheels and fit into a groove made in it. A hole near the ends of the solder allows it to be fastened tightly in place. An enlarged axis, *a*, for winding a cord is fixed to the wheels.

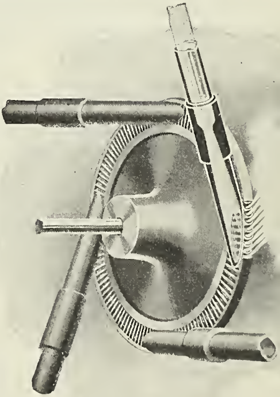
Method. Wind one end of a cord around the axle of one wheel 5 times and the other end of the same cord 5 times around the axle of the other wheel. Pull hard upon the cord at the middle so as to set both into rotation at the same speed. Which rotates the longer?

Double- and Triple-Expansion Engine. Power is derived from steam in the act of expanding. When very high-pressure steam



A double-expansion engine. Why is one cylinder larger than the other?

is used, it is more efficient to use two or more cylinders of different sizes. The triple-expansion engine has three cylinders. High-pressure steam comes first into the small cylinder, where in expanding it pushes the piston along. The steam passes from the exhaust of the smallest cylinder into the second cylinder which is larger than the first. After doing its work in the larger cylinder, the steam of still larger volume and less pressure passes into the third and largest cylinder. Upon leaving the last cylinder it passes into a chamber, where it is cooled and condensed back into water. This condensation gives the engine more power since it creates a vacuum on one side of the piston and thus more effective action from the steam.



The principle of the steam turbine. Notice how the blades of the rotating wheel change the direction of the steam. Why would the addition of stationary blades and then another set of rotating blades increase the power obtained? Where should these blades be placed?

The Steam Turbine. The steam turbine combines the effect of expanding high-pressure steam in steps, and of using a large number of rotating blades against which steam can be effectively directed. After the high-pressure steam first enters the turbine it strikes the blades attached to the rotating shaft. This causes the shaft to turn. The blades in the next row are stationary and they change the direction of the steam so that it may give an effective push to a second row of movable blades. As the steam passes on and its volume has increased, the space is made larger to take care of this. Turbines are the most efficient engines, but they are only suited for use when high speed and continuous running are desired. A large turbine receives steam under the tremendous pressure of 300 pounds per square inch. The shaft may rotate 1800 times a minute, producing a speed of nearly 800 miles an hour at its outer circumference.

How These Types of Engines Are Used. The ordinary single-expansion engine is seen today in small manufacturing plants and in some locomotives. The double- and triple-expansion types are found in the larger and more powerful locomotives and in large manufacturing plants that have many machines that need to be run at high speed. The turbine is used most in plants that generate electricity and in our newer and larger ships, especially ocean passenger liners and battleships. Here they are used for generating electricity which turns the screw propellers of the vessel.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange in proper numerical order. The same word may be used more than once.

useful
uses
used
use
revolution
steam

less
effort
valve
turbine
wasteful
work

atoms
molecules
rotate
expanding
compressed
more

piston
locomotive
energy
efficient
cylinder
cylinders

Molecules of steam have (1)____ energy than the same (2)____ in the liquid state. Compressed (3)____ like (4)____ air has stored (5)____ and is therefore able to perform (6)____. Steam enters the (7)____ of an engine and pushes the (8)____ back and forth. This causes a shaft and flywheel to (9)____. Two or more (10)____ of different sizes are sometimes (11)____ in order to make greater (12)____ of the (13)____ steam. The steam (14)____ is more (15)____ than the type of steam engine used in the (16)____.

PROBLEM TEST

The operation of a reciprocating steam engine involves the application of a number of science facts and principles. *Separate the following list into two groups.*

(1) *Significant,* or those which are made use of.

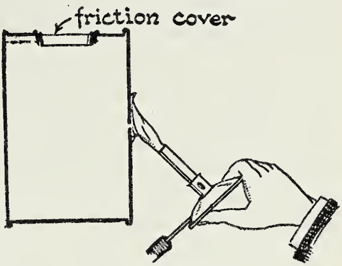
(2) *Irrelevant,* or those which have no important use in the operation of the steam engine.

1. Heat energy may be stored in steam which is under pressure.
2. Expanding steam can do work.
3. Cooling steam causes it to condense.
4. A body at rest tends to remain at rest, but a body in motion tends to continue in motion.
5. The inertia of rest and the inertia of motion can be overcome by proper application of force.
6. Heat for making steam is produced by burning coal.
7. The steam turbine needs no piston.
8. A heavy flywheel helps keep uniform motion when the load is uneven.
9. Watt did much to improve the steam engine.
10. Entrance of steam to the cylinder is controlled by a valve.

PROBLEM IV. HOW DOES THE GAS ENGINE WORK?

The idea of the use of gas in engines began early. In 1680, Huygens, a Dutch physicist, showed that an engine could be driven by exploding gunpowder in a cylinder, the resulting pressure being used to push against a piston. A hundred years later an Englishman named Robert Street suggested that turpentine might be used instead of gunpowder. The first real gas engine was built in France in 1862 and was the forerunner of both the modern automobile engine and the Diesel engine. The latter is rapidly coming into greater use because of its economy. Gas engines should really be called internal explosion engines, because the gases are burned with explosive violence inside the cylinder.

How We Get Power from Gas. The fuel for the internal explosion engine, whether liquid or gas in its natural state, must be in the form of a gas when it enters the engine cylinder. Alcohol, kerosene, and gasoline are three liquids which can be vaporized easily, and therefore are suitable fuels for the gas engine. Alcohol is too expensive, however, for common use. Kerosene finds limited use in slow-speed engines. Gasoline vaporizes readily and is the fuel most commonly used. When the vapor is mixed with the right amount of air and ignited, it explodes and the burning gas generates heat. This heat expands the gases in the cylinder of the engine, drives the piston, and thus gives power.

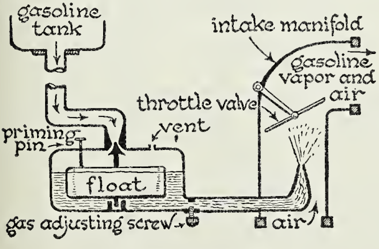


Demonstration 8. Power from Gas

Use a tin can with friction cover. Make a hole in one side about halfway from top to bottom. Put a teaspoonful of gasoline in the can and move it around to wet the sides. Close tightly with the friction cover. Stand it upright and play the gas flame on the can near the hole. The heat vaporizes the gasoline, and when the proper proportions for an explosion are reached, the gas flame ignites the mixture inside the can. Result?

An Explosive Mixture. Experiments with coal gas and air show that the proportion in which the two are mixed is very important in producing an explosive mixture, as not all mixtures will explode. The range of explosive mixtures of coal gas and air is from 93 per cent air and 7 per cent gas to 80 per cent air and 20 per cent gas. When gasoline is vaporized and mixed with air, an explosive mixture is produced.

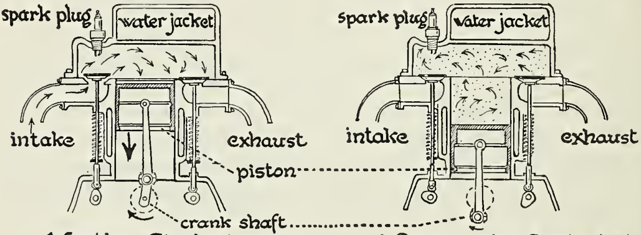
The Carburetor. In operating a gas engine we must mix gasoline vapor and air to prepare the gas for exploding in the cylinders. This is done by means of the carburetor and mixing chamber. The carburetor consists of a chamber holding a small supply of gasoline, with an outlet tube ending in a jet or very small opening. A float in the chamber regulates the height of gasoline.



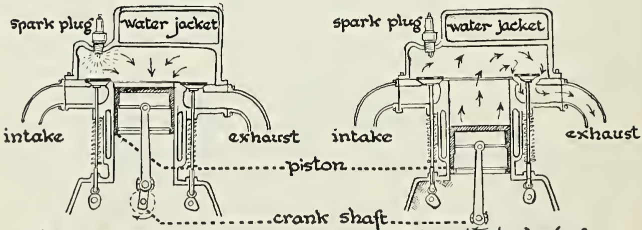
The carburetor.

keeping it just below the top of the jet tube. The jet tube is at the base of the mixing chamber which is joined at the top to the inlet pipes of the engine cylinders. There are openings near the bottom of the mixing chamber to admit air. When a vacuum is produced in the engine cylinder and the pressure is reduced in the mixing chamber, the gasoline spurts upward and an inrush of air mixes with it. This produces the explosive charge, which will be used a little later in the cylinders of the engine. The carburetor requires delicate adjustment to secure the proper proportion of gas and air for best results. In the mixing chamber there is a valve similar to the damper in a stove pipe. This is the throttle which controls the amount of explosive mixture which enters the engine cylinders.

The Four-Cycle Engine. The two forms of gasoline engines found in use are the two-cycle and the four-cycle types. The two-cycle has one power stroke for each revolution of the flywheel. Each of these revolutions involves two strokes of the piston, hence


spark plug
water jacket
intake
exhaust
piston
crank shaft
spark plug
water jacket
intake
exhaust

1. Suction Stroke (down) 2. Compression Stroke (up)


spark plug
water jacket
intake
exhaust
piston
crank shaft
spark plug
water jacket
intake
exhaust

3. Power Stroke (down) 4 Exhaust stroke (up)

The action of valves and piston in a four-cycle gasoline engine. Why are both valves closed during two of the strokes? Are the valves opened and closed on the same principle used in the lift pump?

there is but one power stroke in two strokes of the piston. It is used in some motor cycles and motor boats.

The four-cycle engine is the simpler of the two and is the one used in automobiles. A careful study of the diagrams showing four different strokes will help us to understand how this engine works.

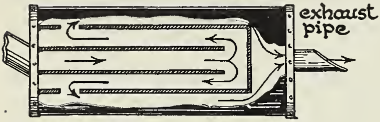
The Intake Stroke or Charging Stroke. When the starting motor turns the crank shaft through half a circle, the piston moves down in the cylinder and produces a partial vacuum in the upper part of the cylinder. During this stroke the inlet valve is open, but the outlet valve remains closed. A mixture of air and gasoline vapor enters the cylinder from the mixing chamber. Is it pulled in or pushed in? At the end of this stroke the inlet valve closes and we have the condition shown in the second diagram, the cylinder being filled with an explosive charge of air and gasoline.

The Compression Stroke. During the next half revolution of the crank, the piston is moving into the cylinder. Both inlet and outlet valves are closed. The charge is compressed into the small space at the top. As the volume of the gas decreases its pressure and temperature rise. Its pressure at the end of the compression stroke may be as high as 100 to 200 pounds per square inch and its temperature 300° F. to 700° F.

The Power Stroke. When the gas is under this high pressure and the piston is just ready to start outward again, an electric spark ignites the charge. The fuel now explodes and heats the gases to over 3000° F. The gases tend to expand and in the confined space produce tremendous pressure. This pressure, amounting to 300 to 700 pounds per square inch, is exerted during the entire stroke. This is called the power stroke or working stroke because it is the only stroke of the four in which energy from the burning fuel is received.

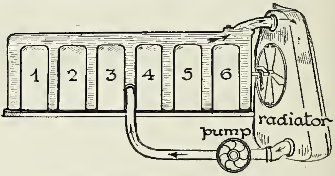
Exhaust Stroke. At the end of the power stroke the cylinder is full of burned gases. As the piston starts back the outlet valve opens, allowing the burned gases to be forced out. At the end of this stroke the outlet valve closes while the inlet valve opens, and the engine is ready to begin the intake stroke again.

The Muffler. As the burned gas leaves the engine cylinder, it is at a pressure much above that of the atmosphere. If allowed to discharge directly into the air at this high pressure, it gives a very loud and objectionable explosive noise. By leading the gases from the engine into a series of chambers, each one larger than the one previously occupied by the gas, the gas expands gradually and finally escapes at a pressure but little above that of the atmosphere.



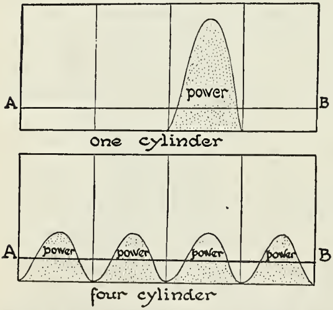
Explain how the muffler works.

Use of Flywheel. Since force is exerted upon the piston during only one of its four strokes, we would have very jerky motion if it were not possible to carry some of this energy over to the other strokes. This is done by communicating the force to a heavy flywheel which is set in motion. The momentum thus given to the flywheel makes it a storehouse of energy for the other three strokes. Do you see why?



What happens in the radiator?

Cooling of the Engine. Since very great heat is generated in the cylinders of the engine, it is necessary to cool them as much as possible. This is done either by making more radiation space on the engine, by using a fan to circulate air over its surface, or by encasing it in a water jacket, and circulating cold water over the cylinders. These are seen in automobile engines, but airplane engines and some automobile engines are air cooled.



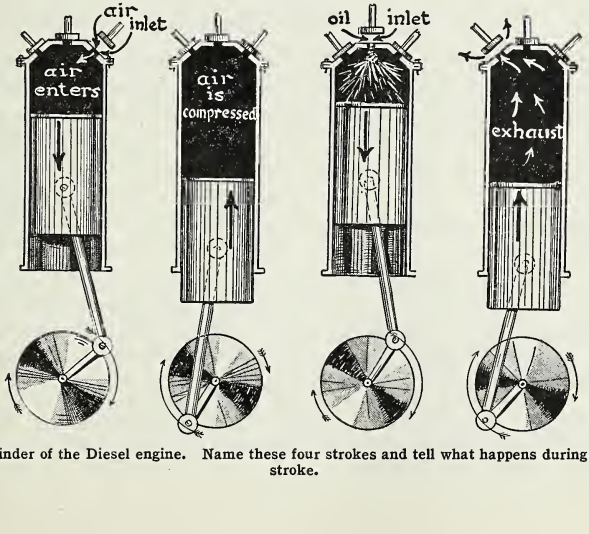
What is the advantage of four cylinders over one cylinder in the production of power?

Water-Cooled Engines. When water is used for cooling, a water jacket surrounds the explosion chamber of the engine. Through this, water is kept in circulation sometimes by gravity, but better by means of a pump driven by the engine.

In the automobile the hot water leaving the water jacket is carried through a radiator where it is cooled rapidly. A fan helps circulate the air around the passages of the radiator. By this means a relatively small amount of water is sufficient to keep the engine cool.

Engines of Many Cylinders. A single large cylinder used with a heavy flywheel will do satisfactory work for many purposes. For automobiles, however, it is desirable to have at least four cylinders. The four piston rods all turn the same main shaft. But the explosions occur at different times, so that during each one of the four strokes of the piston there will be a power stroke in one of the cylinders. By this means each explosion is smaller and a lighter flywheel may be used to give a steady motion. Automobile engines are built with four, six, eight, twelve, and sixteen cylinders, but there is little advantage in the twelve- or sixteen-cylinder engine over that in the six or eight.

Diesel Engine. If you understand the operation of the gas engine, you will have little difficulty in seeing how the Diesel engine works. It is sometimes called an oil engine. In the four-cycle type, air alone is admitted to the cylinder on the intake stroke, and compressed to 600 pounds to the square inch. This



A cylinder of the Diesel engine. Name these four strokes and tell what happens during each stroke.

compression generates so much heat that any oil which is admitted will instantly vaporize and burn, and no spark plug is needed for ignition. Fuel oil is forced into the cylinder under a pressure of about 800 pounds per square inch. It burns in the hot air and keeps sustained pressure on the piston throughout the entire power stroke. The piston then drives out the exhaust gases.

Single-cylinder Diesel engines have been built that develop 200 horsepower and six-cylinder engines that give 12,000 horsepower. These engines work well on any liquid fuel. They *burn* the oil spray in the cylinder rather than explode it. They are, therefore, true *internal combustion engines.* The value of these engines is that they can use a cheap, low-grade fuel; that they convert a higher per cent of the heat developed into mechanical energy than either steam or gas engines; and that they require less space in a boat than a steam plant for the same power. They are desirable for submarines and for freight boats since they allow more space for cargo. Diesel-electric engines are being used also to generate electricity in cars, thus replacing steam locomotives for drawing trains. A successful Diesel engine has been built for use in airplanes.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange in proper numerical order. The same word may be used more than once.

air
water
steam
compound
valve
piston
one
two
three
four
carburetor
explosion
cylinder
gas
power
end
ignites
mixture
exhaust
combustion

One difference between the common gas engine and the Diesel type is that a gas engine is an internal (1)____ engine and the Diesel is an internal (2)____ engine. In a gas engine the piston compresses a (3)____ of (4)____ and (5)____, while in the Diesel it compresses only (6)____. In the four-cycle engine there is (7)____ power stroke in (8)____ strokes of the piston. The advantage of using more than one (9)____ is that the (10)____ strokes come nearer together. The (11)____ helps to prepare the mixture of (12)____ and (13)____ which enters the engine for ignition.

PROBLEM TEST

The operation of the four-cycle gasoline engine involves the application of a number of science facts and principles. *Separate the list which follows into two groups.*

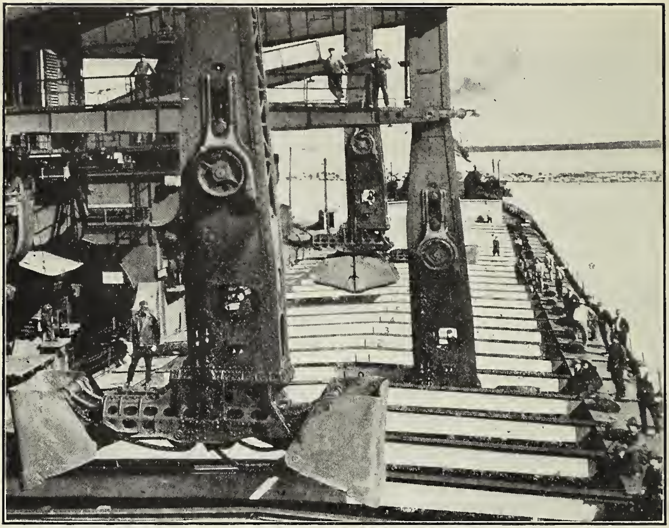
(1) *Significant*
(2) *Irrelevant*

1. Gasoline is a combustible fuel.
2. Volatile liquids are easily vaporized.
3. Heat causes gases to expand or else to increase their pressure.
4. Cooling a gas causes it to contract or else to decrease the pressure.
5. Gasoline is a dangerous liquid to have near open flames.
6. Much noise results from operating the engine when no muffler is used.
7. A mixture of gasoline and air is explosive.
8. Heat from an electric spark is sufficient to ignite the explosive mixture.
9. Momentum of a heavy flywheel moves the piston three out of every four strokes.
10. The largest use of the gasoline engine is in the automobile.

PROBLEM V. HOW IS HEAT USED IN SOME INDUSTRIES?

We have seen that when fuels are burned, heat is given off, and that this heat can be measured in heat units. It follows, then, that when heat is provided power is developed that can be used in industry. While we have very many industries which use heat, perhaps the one on which the prosperity of our country most depends is that of iron and steel.

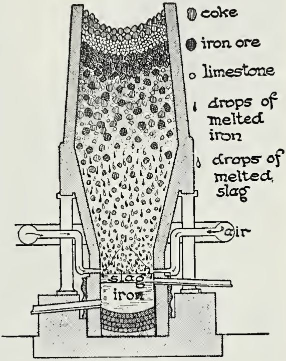
Where Iron Comes From. Steel is closely connected with iron. Iron ore in this country is found most plentifully in the great open pit mines of Minnesota. Here the iron oxide, soft and easy to mine, is taken out with great steam shovels, loaded on to ore cars, shipped cheaply by ore boats down the Great Lakes to Cleveland, Chicago, Buffalo, and by rail to Pittsburgh. An ore boat 600 feet long and 60 feet wide can be loaded with over 11,000 tons of iron ore in an hour by ore chutes, and unloaded in three hours' time by means of great unloaders which scoop up huge bucketfuls weighing 17 tons.



A modern ore boat showing its huge size and the unloading buckets in action. At which end of the trip is this boat, Duluth or Cleveland? Give reasons for your answer.

How Iron Is Made from Ore. The process of getting iron from iron ore requires an extremely hot fire. For this purpose coke is used. Iron ore is oxide of iron mixed with some impurities such as sulphur and rock material. The process by which iron is obtained is called *smelting*. In order to separate the iron from the other materials, it is placed in a blast furnace which smelts out about 2000 tons of ore a day, and may work continuously day and night every day in the year. Iron ore is mixed with coke and limestone and is fed into the top of the furnace, while a supply of air heated to from 1200° F. to 1400° F. is sent in under high pressure. The coke serves a double purpose. It burns, thus producing heat, and it removes oxygen from the ore. The limestone is called the *flux* because it melts readily and unites with the earth impurities, forming what is known as *slag*. The slag, being lighter than the molten iron, floats on top of it. From time to time a tap hole near the bottom of the furnace is opened to let the liquid iron run out.

This impure iron is cast in molds into bars called "pigs," which are later used in the manufacture of steel. Pig iron contains approximately 2½ per cent to 4 per cent carbon. By removal of the impurities from pig iron a tough form of iron known as wrought iron containing only 0.2 per cent carbon is produced. Steel has a carbon content between that of wrought iron and pig iron.



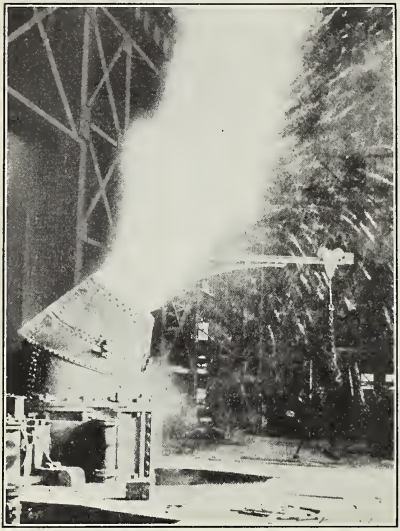
Read your text and tell how pure iron is obtained.

Steel Making. In making ordinary steel, molten pig iron is poured into a Bessemer converter. Blasts of hot air pass through the iron and burn out the impurities, including the carbon. After this is done the right quantity of carbon and manganese is added. The Bessemer process is rapid. A converter full of pig iron — 20 tons — can be changed into steel in 20 minutes.

There are other methods of making steel which have advantages over the Bessemer process for special kinds of steel. Many different metals may be mixed with iron in producing alloy steels. The electric furnace is much used in producing steel alloys, the kind of steel depending on the substance added to it. For example, nickel steel is used for making rails and auto parts. Chromium steel goes into armor plate and rustproof auto trimmings. Tungsten steel is tough and is used for tools requiring high strength. Vanadium steel is used for axles and auto springs. One kind of "stainless steel" used in making cutlery is an alloy of steel and chromium.

What Is Steel? Steel, then, is nothing but iron with impurities removed and a small amount of carbon and usually some other metal added. Its properties depend upon the amount of carbon and the kind of metals mixed with it. When red hot steel is cooled slowly, it becomes soft; when cooled suddenly, it becomes hard and brittle. Tempering is the process of heating and cooling used to produce the desired properties of softness or hardness in the steel. Steel for tools and cutting edges is tempered.

Cutting and Welding of Steel. We have already seen that heat causes molecules of substances to become more active. As heat increases, their motion becomes greater. Under extreme heat, molecules may change their position entirely and separate. Such movement results in the change of a substance from a solid to a liquid. Advantage is taken of this in cutting steel. A very thin but intensely hot flame is produced which will melt right through steel plate or thick steel beams. The oxyhydrogen, oxyacetylene, and the atomic hydrogen flames are used for this purpose.



Publishers' Photo Service

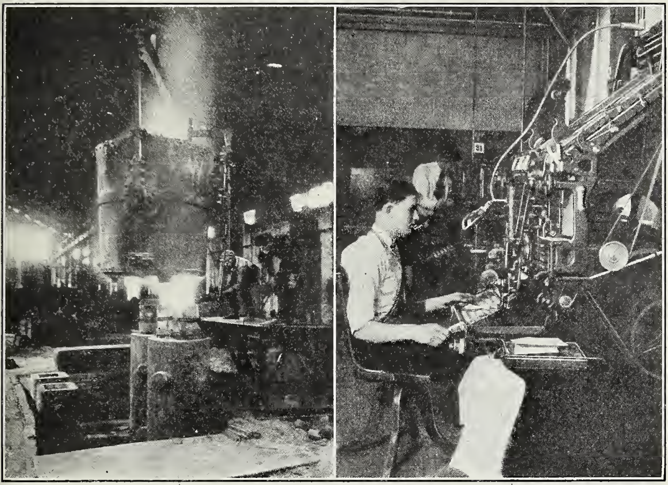
A Bessemer converter in action. Note the intense heat used. What is the reason for using such heat?

When two pieces of steel are heated nearly to a plastic state, they can be hammered together into one piece in a process called *welding*. Rivets can be headed over when the steel is very hot because of the freer movement of the molecules at high temperatures.

Metal Castings. We have seen that liquids like water when cooled become solids, and solids when heated become liquids. Water and iron expand when they solidify, while many substances like paraffin and zinc contract. When a casting mold is filled with paraffin, it will not be quite full when cooled. Silver and gold, like zinc, shrink when cooled. Coins of silver must be stamped rather than cast because they will not fill out the mold.

The printing industry is dependent upon the rapid production of letters by casting. Type metal, which is an alloy made of antimony, tin, and lead, has the useful property of expanding when the liquid solidifies. The linotype machine pours liquid type metal into molds as the typesetter sits at the machine and types out a line of print. This cools and solidifies at once so that it can be used for immediate printing.

Many objects are made of cast iron. A model of the desired object is made. This is packed carefully in molds and in such a way that the mold can be taken apart to remove the model. An opening is left in which to pour the liquid iron and small holes to allow air to escape. The parts of the mold are clamped firmly together. The liquid iron is poured in, and after cooling the mold is removed. Objects made of cast iron are brittle as compared with steel, but for many purposes where toughness and strength are not required the castings are just as serviceable and, of course, they cost less.



Society for Visual Education

Two industries that depend upon the fact that metals when cooled become solids. Do you know what they are?

Heat in Other Industries. As in the production of iron from its ores heat plays a somewhat similar role in the separation of many other metals from their ores. As examples of this we may mention lead, tin, copper, and mercury. Compounds of metals are much used in paints, and heat is an essential in the production of many of these compounds. The great cement industries, the manufacture of lime, and the refining of petroleum cannot be carried on without heat. Perhaps there are some important industries in your own locality. If so, try to find out in what ways they are dependent upon heat.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange in proper numerical order. The same word may be used more than once.

copper
mercury
carbon
blast
oxygen
air
melting
expanding
fire
heat
expand
solid
stove
flame
production
ore
become
furnace
impurities
solidifying
steels
cut
pig
metals

Oxygen is removed from iron (1)____ in a (2)____ (3)____ by combining it with (4)____ supplied in the form of coke. The start in the (5)____ of steel is (6)____ iron. This must have the (7)____ and at least some of the (8)____ removed before it can (9)____ steel. Special kinds of (10)____ are produced by mixing other (11)____ with the iron and always including a little (12)____. Steel can be (13)____ with a thin and very hot (14)____ better than with a saw. Castings can only be made from metals that (15)____ upon (16)____.

PROBLEM TEST

Rearrange the parts in italics to give the best statements of facts. Indicate rearrangement by pairing of figures and letters.

1. Hot-air blown into the blast furnace *requires oxygen to produce heat.* (*a*)
2. Liquid pig iron when poured into a mold *combines with coke.* (*b*)
3. Hot air blown through a Bessemer converter *takes oxygen from iron ore.* (*c*)
4. Coke in the process of smelting iron *becomes hard and brittle.* (*d*)
5. Red hot steel plunged into ice water *removes the earth impurities.* (*e*)

6. Limestone in the production of iron *increases in size upon solidifying.* (*f*)

7. Coke or some product from coke and air *unites with carbon.* (*g*)

◆

REVIEW SUMMARY

The following generalizations are suggested as a start for your development of a detailed review summary.

1. Energy from the sun is stored in fuels.
2. Gaseous fuels can be obtained from natural solid and liquid fuels.
3. Heat through the agency of steam can give mechanical energy.
4. Chemical action between gases in an enclosed space yields mechanical energy.
5. Many useful products are obtained from natural raw materials through the use of heat.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × 3⅓.*

I. **The following factors have aided in the formation of coal:** (1) the surface of the earth in places has undergone changes in elevation; (2) vegetation is luxuriant in tropical forests today; (3) the deeper down in the earth the hotter it gets; (4) there are many bogs and marshes where men dig peat formed from moss; (5) the pressure one mile deep in the earth is very great.

II. **In the manufacture of coal gas:** (6) an important fuel produced is charcoal; (7) large amounts of anthracite coal are used; (8) moth balls are made; (9) a gas which is nearly half hydrogen results; (10) a gas containing about 30% carbon monoxide is produced.

III. **The value of steam in a steam engine depends upon the principle that:** (11) a hot gas has much heat stored in it; (12) a compressed gas can expand and do mechanical work; (13) steam is hotter than air and so has more energy; (14) the piston in the cylinder compresses the steam and gives it more force; (15) burning coal can change water to steam.

IV. **The force for running the gas engine and Diesel engine comes from the:** (16) expansion of hot gases following the burning in the cylinder; (17) electric spark or heat of compression of the gases; (18) use of a heavy flywheel; (19) mixing of air with gasoline or oil vapor; (20) the cooling system which removes excess of heat.

V. **In making steel from iron ore heat:** (21) is used to melt the iron ore; (22) is produced by burning coke; (23) is used in melting iron for making objects of cast iron; (24) helps to remove the impurities in the Bessemer process; (25) is necessary only in the blast furnace.

VI. **Gasoline is produced commercially:** (26) as a by-product in manufacturing coal gas; (27) by destructive distillation of soft coal; (28) from oils by a process of "cracking"; (29) by fractional distillation of crude petroleum; (30) by pumps extending into oil wells.

PRACTICAL PROBLEMS

1. Which is more useful, the steam engine or the gas engine? Make out lists of the things done by steam engines and of those done by gas engines. Try to evaluate them in reaching your conclusion.
2. How can you tell when you see a steam engine whether it is a single- or double-expansion engine or a turbine engine?
3. Can you give more than one reason why a Diesel engine is more economically used than gasoline engines for train service?
4. Trace the changes in energy from the sun that have made possible the production of a rail of Bessemer steel.
5. How is the question of heat related to that of lubrication of a machine?

INTERESTING THINGS TO READ ABOUT

1. Find out how men can reproduce models of the ancient trees that were changed into coal even to the delicate markings on the bark.
2. Discovery of oil in America.
3. How does a two-cycle differ from a four-cycle gasoline engine?
4. How is the metal lead produced from its ores?
5. In what way was Edison once interested in the cement industry?
6. From periodicals learn what you can about recent developments in the use of Diesel engines.
7. What is stellite and for what used?
8. An account of James Watt.

LEISURE TIME ACTIVITIES

1. **Field trip.** Try to find sphagnum moss growing in a swamp or bog. Dig through the surface; examine the material found one, two, or three feet below the surface. Visit a salt-water marsh; try to find evidence of peat formation.

2. **Kinds of coal.** Visit your coal dealer. Get specimens of the different sizes of hard coal, buckwheat, pea, nut, stove, egg, and furnace for your personal museum. Find out the cost of each per ton and where and how each is used. Also get a sample of soft coal and, if possible, a briquette to add to your collection.

3. **Steam power.** Get a pressure-cover tin can and a four-inch length of small copper tubing such as is used to carry gasoline in the auto. (Visit an automobile-repair junk pile.) Make a hole in one side of the can near the top. Solder one end of the tube over this hole. This is to deliver steam. Make a wheel with paddles. A spool with six or eight blades of tin will do. Support this on an axle in front of the steam outlet pipe. Heat the water and boil it rapidly to make a strong current of steam. Adjust the wheel at the correct level so that it will revolve. Will this run a toy machine?

SCIENCE CLUB ACTIVITIES

1. **A visit to the gas works.** Arrange with the gas company for a trip to the local gas works. The company will gladly furnish guides who will explain the process to you.

2. **The gasoline engine.** Show the moving picture prepared by Eastman Teaching Films, Inc., "The 4-Cycle Gasoline Engine."

3. **Industrial use of heat.** Find out how the different local industries use heat. A survey may be made; assign certain territory to each member for him to canvas and report to the club.

4. **A debate.** Choose debaters and prepare a debate upon this question: Resolved: That fire makes a larger contribution to civilization through its use in industries than it does through its use in homes.

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Hough, Walter R., *Story of Fire.* Doubleday, Doran and Co., 1928.
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Survey Questions

How are colored lights produced?
Why is it better not to study facing a window?
How is glare prevented in factories?
How is factory lighting related to efficiency of the workers?
What is meant by flood lighting?
How do lenses produce images?
Did you ever see an unreal image?
Do you know the difference between the reflecting and the refracting telescope?
Have you ever seen a spectroscope?
How many different ways of using signal lights can you name?
Are the X-rays a form of light?

Galloway

UNIT VI

LIGHT AND OTHER RADIATIONS IN SCIENCE AND INDUSTRY

PREVIEW

No one who visited the Century of Progress Exposition can ever forget the thrill that came when it was announced that the great telescope in one of the co-operative observatories would pick up light from the star Arcturus, light which left the star 40 years ago, would transform this light by a photoelectric cell to electrical energy, amplify it, and speed it over wires to be used in turning on the lights. As you stood there in the Court of Honor and saw building after building stand out, illuminated in colors, while thousands of lights burst forth on all sides, you felt that light played a very wonderful part in the world of today. And when you wandered from building to building and saw the marvels of light, you were astonished to know the candle power used within the Fair grounds. One battery of search lights alone had a lighting capacity of nearly two billion candle power. There were thousands of incandescent bulbs used for exterior decoration alone. These bulbs varied from 300 to 10,000 watts. Arc lights and flood lights were used to bring out colors and architectural details. Many of the exhibit buildings were actually windowless, the exhibitors preferring modern artificial illumination because of its softness and lack of glare. The whole exposition gave you many ideas about color in lighting. These colored lights enclosed in glass tubes of new design and huge size were produced by passing electricity of high voltage through tubes filled with different gases. For example, red color is caused by neon gas in a clear glass tube, blue by a mixture of neon and mercury in a clear glass tube, yellow by helium gas in a yellow tube, and green by mercury vapor in a yellow tube. This exhibit disclosed the possibilities of such lights not only in advertising, but in the ornamentation of our buildings.

Today as never before industry is making use of scientific lighting. Not only are lights placed differently, but new and better methods are being used to make industry more efficient and safe for the workers. The pages that follow will explain some of these things.

In your earlier study of light, even if those facts and principles are not directly used in very much of the discussion which follows in this unit, yet they are involved in the uses explained here. It will add greatly to your understanding of the subject if you fully understand the chief principles mentioned below.

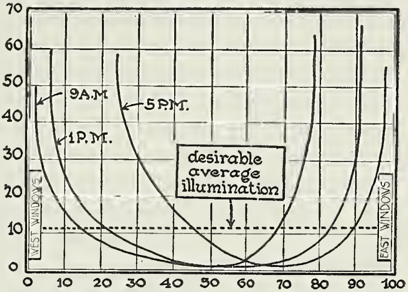
1. Light is a form of radiant energy which makes objects visible.
2. Light may be reflected, refracted, and absorbed.
3. Light is produced at the expense of some other form of energy.

PROBLEM I. HOW LIGHT IS USED IN INDUSTRY

Lighting Our Schools. In schoolrooms it is essential to have light come from all sides so that desks may be placed to allow proper lighting. The teacher's desk may face the light, while light comes to the children's desks from the rear and sides. In the laboratory light spaces under the windows are used for growing plants, carrying on experiments, or doing other laboratory work where much light is needed. In some buildings where ground space is plentiful, the rooms are spread out and natural light is obtained from skylights which can have shades drawn over them to keep out unnecessary sunlight. Sometimes such skylights are filled with ribbed glass so as to diffuse the light which comes through. Artificial light in schools is usually indirect or semi-indirect with careful provision made for the prevention of glare.

Lighting Our Factories. When ground space is expensive, and the buildings high, modern factory buildings may have windows on more than one side, while the rooms that are not lighted by direct sunlight are furnished with prism or factory-ribbed glass. This glass bends the light so that more of it gets in. When factories can be spread out in low buildings, the sawtooth method of construction is used, with glass skylights facing the northern sky. Windows must have translucent window shades so that when too much light is available, it can be shut out, for rapid changes in light are very fatiguing for the workers.

Daylight Factory Illumination. Many industries are carried on in factories. But relatively few of them can have the sawtooth skylighting. In cities there are usually many stories or lofts to a building, which make uniform natural lighting impossible. The graph shows a factory 100 feet wide with east and west windows in latitude of New York City. Illumination tests were made at 9 A.M., 1 P.M., and 5 P.M. on a clear June day. The light was far greater than needed near the windows but at no time as much as was desirable in the center of the room. The conditions could be improved by the use of shades to cut down the intense light at the windows and the use of artificial illumination in the center.



Tests have been made that show that most factories have very unequal illumination. Can you explain the diagram? The vertical scale indicates foot candles.

Artificial Factory Illumination. For night lighting, lights are placed so that even illumination is given the room rather than intense light placed directly over each machine. Glare is avoided by having indirect lighting and frosted glass bulbs. Tests made by engineers show that where illumination in poorly lighted factories is increased to give good working conditions, the increase in production and in efficiency is very marked. Some industries use long mercury vapor lamps for illumination, which give a clear greenish light. This light is cheap, it is lacking in red rays, is very restful to the eyes, and is used for certain types of close work.

Advantages of Good Factory Illumination. The advantages of good factory illumination are:

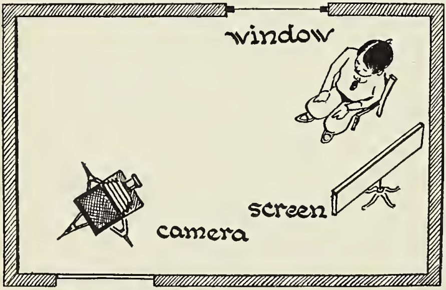
1. Greater contentment and greater comfort to the workers, which makes for greater production at the same cost of labor.

2. Greater accuracy of work is possible, thus making for improved quality of goods.

3. There is little eyestrain and fatigue and consequently fewer accidents.

Industrial Accidents and Poor Lighting. It has been shown by the statistics of a large insurance company that in 1919 there were more than 2,000,000 industrial accidents, of which 25,000 were fatal. Of these a considerable number were due to poor lighting. Conditions are much improved today. Industry will be making a steady decrease in accidents when it has sold the idea of "Safety First" to the worker, and we shall be able to eliminate accidents almost completely, because it is the careless and thoughtless workers who get into trouble.

Stage Lighting. Effective stage lighting requires special equipment. There are the footlights, overhead lights, and side or wing lights and besides there must be back-stage lighting to kill shadows. Resistance control for dimming lights and various circuits for different colored bulbs are required. Color screens for flood lights and for the spotlight are necessary to give variety and the color which fits the production of moonlight effects, evening scenes, and bright daylight. In really artistic productions one must study the effect of the colored lights upon the painted scenery and the costumes and be sure they blend well to make harmonious combinations.



Explain what you would do to take a good picture of this boy.

Lighting for Photography. The amateur cannot hope to have a well-lighted photographic studio at home, but, with the speed of films and the new lighting devices now available, home pictures may be taken indoors either by day or by night. The amateur, however, seldom can see the fine differences in light and shade that one finds in a really good studio portrait. The same person may be taken under different lighting conditions, and one exposure will result in a hideous picture while the other will be a beautiful portrait. Full-front lighting gives a flat picture; there must be shadow to show form. In general there must be more than one source of light. The two sides of the face should not be equally lighted. If taking a portrait at home by light from a window, reflect some of the light from the window to the dark side of the face by means of a white sheet used for a screen. The diagram shows its position. For night pictures, the best light is secured by using the new photoflood lamps. These burn like ordinary bulbs, but are ever so much brighter. Do not burn them longer than needed as they are short lived. Then there are the flashlights and the flash bulbs which give no smoke. You will need to experiment a little to find how to get the best results with your camera and the special conditions you have at home.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

teacher
front
pupil
blackboard
back
inaccurate
candles
little
darkness
natural
artificial
neutral
efficiency
dark
quantity
shadow
shading
greater
much
side
impossible
accidents
possible
lighting

In the classroom it is better to have the light come to the (1)____ from the (2)____ or rear. Uniform (3)____ lighting in factories is (4)____. Improvement in (5)____ in many factories has been followed by increase in (6)____. Other results from good factory (7)____ are (8)____ comfort, greater (9)____ of work, and fewer (10)____. In most factories the light from daylight is apt to be too (11)____ near the windows and too (12)____ in the middle of the room. This can be remedied by (13)____ the windows and using (14)____ (15)____ in the interior.

PROBLEM TEST

Each introductory phrase below is followed by six words or phrases. Five of them relate directly to the idea expressed in the introductory phrase. In each case state (1) *the* principles involved *and* (2) its use or effect. *Cross out the one which does not fit in with the group.*

I. *Control of Window Light*
    1. ribbed glass
    2. blinds
    3. shades
    4. trees
    5. foot-candles
    6. awnings

II. *Control of Artificial Factory Lighting*
    1. power of lamps
    2. location of lamps
    3. diffusion devices
    4. reflectors
    5. glare
    6. dusty shades and globes

III. *Stage Lighting Needs*
    1. footlights
    2. spotlight
    3. photoflood lamps
    4. light dimmers
    5. overhead lights
    6. color screens

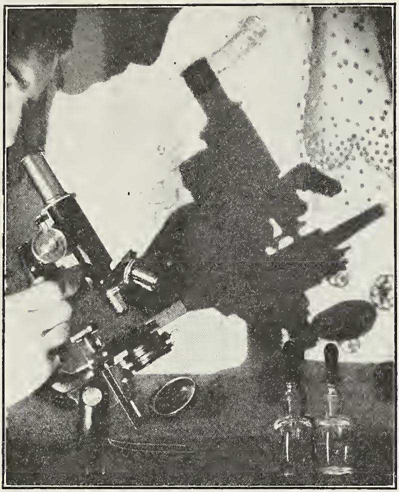
PROBLEM II. WHAT INSTRUMENTS MAKE USE OF LIGHT?

If you were to go into the laboratory of some big manufacturing plant, you would see there many instruments containing lenses which use light. Such instruments are the microscope, spectroscope, polariscope, and many others. Let us see how lenses are used in science.

What Lenses Do to Light. The use of lenses depends on the ability of glass to bend or refract rays of light. Rays which are parallel to the principal axis are bent so that they pass through the principal focus on the other side of the lens. All rays which pass through the optical center are not refracted but continue in a straight line.

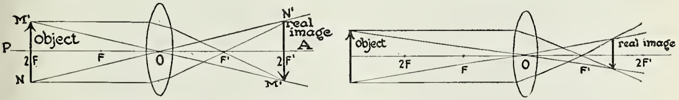
The line running through the center of a convex lens at right angles to the axis of the lens is called the principal axis (PA). A point equidistant from all parts of the curved surface is the center of curvature. This point is also, for practical purposes, the principal focus of the lens (F). The center of the lens is the optical center (O).

These two lines — the one parallel to the principal axis bent through (F) and the one through (O) not bent — are the construction lines that can be used to locate the position of the image of an object. The image will be located where the two lines cross. Study the diagrams below to see how the image may differ from the object and why it is often inverted. If the light really reaches the place where these lines cross, a *real image* results. If it does not actually reach the point where the lines cross, an *unreal image* or *virtual image* results. An unreal image is one which can be seen, but which cannot be received on a screen which is placed where the image apparently is located. We see an unreal image in a concave lens, in a mirror, and in a simple microscope. The demonstration which follows will help you to get a better idea of the formation of images.



Class in Photography, John Muir Technical High School, Pasadena, California

A compound microscope in use. How many of the parts do you know the names of? The use of?



What is a real image? Where is the principal focus? Why is the image in the right-hand drawing smaller than the object?

Demonstration 1. How Are Images Made with a Double Convex Lens?

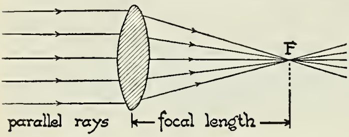
Materials. Two double convex lenses of different thickness, white screen, and large electric bulb.

Method. 1. *To find focal length.* Hold a double convex lens in the sunlight at right angles to the rays. Place screen of white paper back of lens and adjust distance between them until the spot of light — the sun's image — is the smallest. This point on the screen where the sun's rays meet is called the principal focus of the lens; the distance from it to the lens is called the focal length of the lens. Compare the focal length of a thick lens with that of a thin lens.

2. *Focusing as it is done in the camera.* Hold a double convex lens about four times its focal length from a large electric bulb or candle in a partially darkened room. Move a screen of white cardboard back and forth behind the lens until a sharp image of the filament is seen in it. Move the lens toward the light until a second sharp image results. Measure the distances.

3. *A simple microscope.* Hold the lens over a printed page so that the letters are between the lens and the principal focus. Look through the lens. Compare the size of the image with that of the real letters.

Observations. How can lenses be used to produce clear images? Can a lens be used to produce different sized images of an object? This experiment explains how lenses produce the images by bringing the rays of light which pass through them to a focus. Explain how the light in passing through the lens apparently changes the size of the object. Use a diagram.



Images. If we examine a reading glass we shall find that the lens bulges out at the center on both sides; it is called a double convex lens. If we look through such a lens, we may see an image or we may project the image on a screen. When the image can be seen on the screen, it is a *real image.* When it is seen by looking through the lens, it is a *virtual or unreal image.* The ordinary microscope is a double convex lens and has a shorter focal length than the reading glass. Both have the same principle of image formation. The compound microscope has a very small objective lens which makes an enlarged image of a very small object. The large lens in the eyepiece is used as a simple microscope and makes a still larger image of the image made by the objective lens.

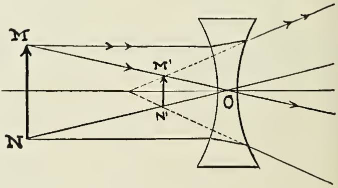
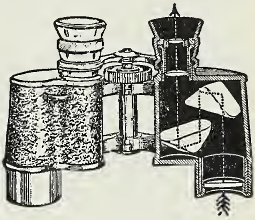


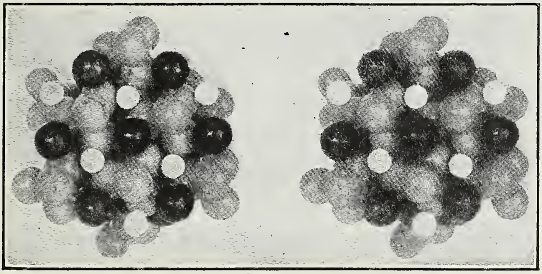
Image produced by a double concave lens. Is it real or virtual? Why?

Another kind of lens, which is thicker at the outer edges, is called the concave lens, which never gives a real image. It gives a small image of a distant object and a magnified image of an object within its focal length. These are unreal images.

Opera and Field Glasses. Such instruments make use of the principle that Galileo used in his first telescope. He ground two pieces of glass and arranged them in a tube through which he could look. By a combination of concave and convex lenses an erect unreal image is produced which is three or four times the size of the object as it would appear to the unaided eye. Galileo's best telescope magnified objects 30 times. The greatest disadvantage of the opera glass is that it covers only a small field of vision. To increase that a longer tube might be used, as in the telescope, but the instrument would be too long for ordinary use. The equivalent of a long tube is secured by the use of two right-angle prisms which are arranged to carry the light back and forth in an instrument called the *prism binocular*. The effect of a tube nearly three times as long is secured in this way. The lenses are all convex, as in the telescope used today. The image which with lenses alone would be upside down is brought right side up by



The binocular makes use of two prisms to reflect light and makes the effective distance between the lenses greater than their actual distance apart. What advantage has this?

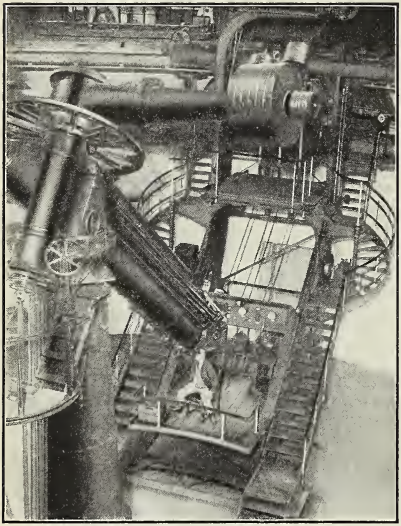


Fisher Scientific Co.

Hold a narrow ruler about halfway from the eyes to the illustration so that the left eye sees only the left-hand picture and the right eye sees only the right-hand picture. Then the two pictures blend into one which seems to have three dimensions. Explain why this is so. (Read your text, page 170.)

reflection through the prism. The ends of the instrument which receive light are farther apart than the eyes, which helps to give a more pronounced effect of depth than when the eyes alone are used.

Binocular Vision and the Stereoscope. The left eye sees more of the left side of an object than the right eye, which in turn sees more of the right side of an object than the left eye. But the brain, where we are conscious of the impression, puts these two images together in such a way that we see them as a single object that has solidity or depth. This is known as binocular (bĭn-ŏk′ŭ-l*ă*r) vision. The stereoscope (stĕr′ē-ō-skōp) is an instrument used to look at two photographic pictures of the same object or scene from two points of view, one representing what would be seen with the right eye, the other with the left eye. When such photographs are looked at under proper conditions, the two views are combined by binocular vision and give the appearance of one picture having depth.

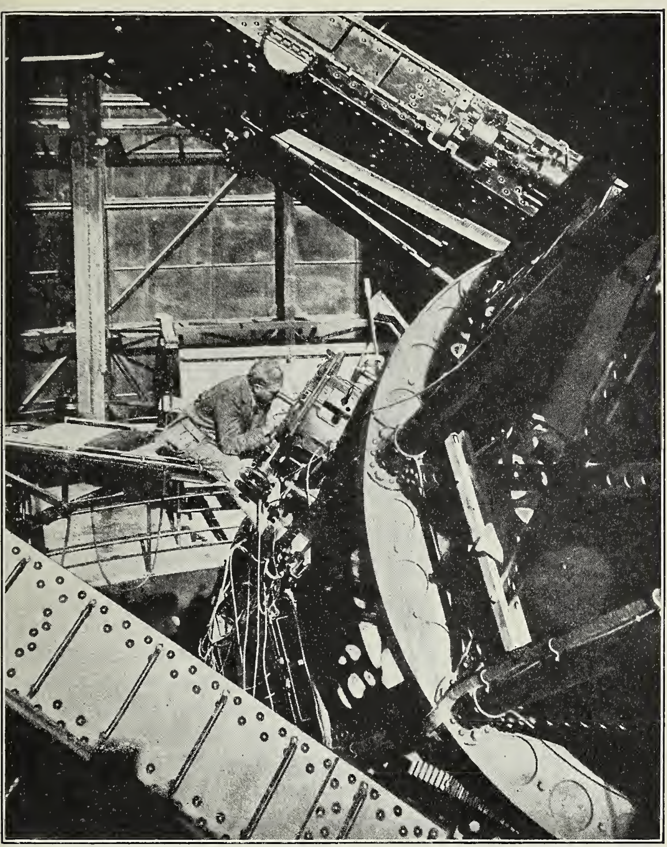


R. I. Nesmith

A huge refracting telescope at Potsdam, Germany, used for delicate photographic work. Study the diagram on page 172 and try to find the parts shown in this photograph.

In the stereoscope are two lenses through which you get a magnified image of the picture, but the result of stereoscopic vision can be obtained from two stereoscopic pictures properly placed and observed without lenses to magnify the image, as can be determined for yourself by observation according to directions given with the picture of the two models shown on page 169.

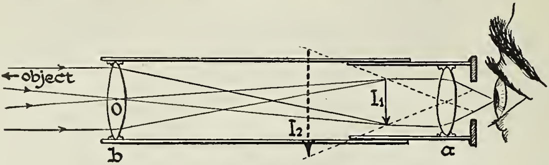
The Refracting Telescope. The refracting telescope differs from a microscope entirely in the arrangement of lenses. A



Galloway

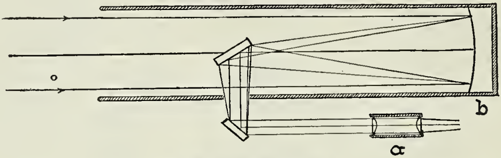
The **100**-inch reflecting telescope on Mount Wilson, Pasadena, California. Compare with the diagram on page **172**, and try to identify some of the parts shown in the photograph.

microscope produces an enlarged image of very small objects, but the telescope is used to get the image of a body so far away that it appears small to the unaided eye. In the refracting telescope the objective lens is of larger diameter and produces a real image. The eyepiece acts as a simple microscope and produces an enlarged virtual or unreal image of the image made by the objective lens. The telescope cannot make the object appear larger than it really is, but the image seen is larger than could be seen without it. Thus the effect is the same as if the object were brought nearer.



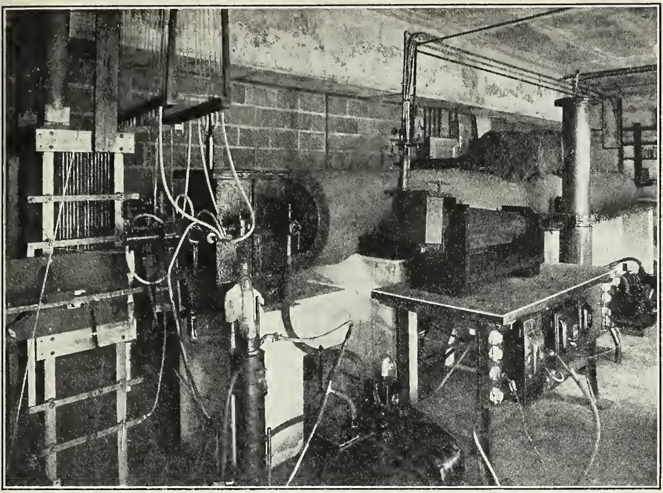
The refracting telescope.

The Reflecting Telescope. In a reflecting telescope a cylinder of large diameter is used to bring in as much light as possible to a curved mirror at its base. This mirror brings all the light it receives to a focus at a single point. The image at this point is observed through a lens eyepiece. The reflector now in use at the Mount Wilson Observatory has a mirror 100 inches in diameter. A mirror 200 inches in diameter is now in process for the construction of a reflecting telescope that will be four times as powerful as the best now in use. The grinding of these mirrors must be very exact and requires years of labor to produce a satisfactory reflector.



The reflecting telescope.

The Spectroscope. An instrument used much in science is the spectroscope. In this instrument a prism is used to resolve light into its spectrum colors. Different substances in vapor form are able to absorb certain colors from the spectrum and produce dark lines in the spectrum. The position of these lines makes it possible to identify substances through which the radiations pass. With this instrument the astronomers learn about the composition of stars, and what changes are going on in matter. With it the chemist can tell the presence of certain elements which



Mass. Institute of Technology

One of the largest spectroscopes in the world is in use at the Massachusetts Institute of Technology. What are some of the uses of the spectroscope? This one works in a vacuum and is used in the study of the ultra-violet region of the spectrum.

are present in such small quantities that they will not affect his most delicate balance. It was by use of the spectroscope that the Danish scientist Bohr learned about the internal structure of the atom and gave us a mechanical picture of it.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

plane
thinner
thicker
vertical
slanting
horizontal
distance
curved
lens
mirror
mirrors
lenses
object
parallel
increases
different
principal
heavier
image
concave
convex
focus
images
refracting
smaller
reflecting
magnify
same

Convex (1)____ are (2)____ in the middle than at the edge. A (3)____ lens will bring rays of light (4)____ to the principal axis to a point at the principal (5)____. The size of the image depends upon the (6)____ of the (7)____ from the (8)____. A (9)____ lens always gives a virtual image that is (10)____ than the object when the object is farther away than the principal focus. A (11)____ telescope uses two lenses, one to produce a nearby (12)____ and the other to (13)____it. The (14)____ telescope uses a large concave (15)____ to collect a large amount of light which it brings to a (16)____. In a simple microscope the (17)____ must be placed between the (18)____ and the principal (19)____; the image will be on the (20)____ side of the lens.

PROBLEM TEST

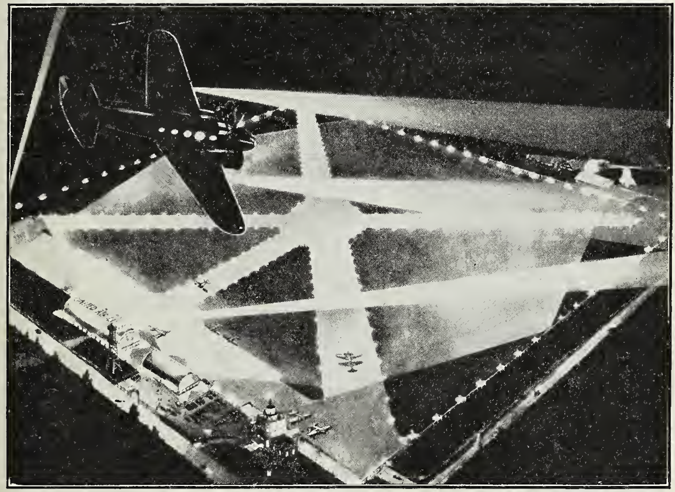
There are many science facts and principles involved in the use of double convex lens in magnifying small objects. *Separate the facts listed below into two groups, those which are significant or are involved in the use of the microscope and those which are irrelevant or are not involved in its use.*

1. Curve mirror produces real images.
2. Light travels in straight lines in ether and air.
3. Light travels in straight lines in glass.
4. Light rays are refracted upon going into a medium of different density.
5. We judge the size of an object by the visual angle.
6. The lens increases the visual angle of the rays that make the object visible.
7. The rays are bent by a lens and make a virtual image.
8. The glass causes a greater bending of the violet rays than it does of the red rays.
9. Glass is transparent.
10. Glass absorbs some of the light that enters it.

PROBLEM III. HOW IS LIGHT USED FOR SIGNALING?

Uses of Signals. If you were crossing the continent in an automobile and did any driving at night, you would be surprised to find how often you would see the flash of an airplane beacon. You often see the green and red "eyes" of the railroad signals, and you are frequently halted by the red of the traffic signal on your own highway. This is a very different world from that in which our fathers lived. Our fathers would never have thought of any lighthouses other than those on the seacoast, and yet today they are scattered all over the continent.

Airplane Beacons. There are some 15,000 miles of civil airways which are provided with beacons about 10 miles apart. In February, 1932, there were 1477 such lights. The standard airplane beacon is a skeleton steel tower 51 feet in height, although such towers may run 30 or 40 feet higher. Each tower has a directional arrow 54 feet in length which points to the next beacon. Beacons are known by numbers based on mileage from the start of the route, *e.g.* beacon 36 would be 36 miles from the starting point of a given route. Beacons may have fixed or flashing lights and may be white, red, or green. These powerful lights are built up to greater power by lenses and reflectors and may be seen for a distance of from 15 to 20 miles. Fixed-course lights throw beams on the ground, directing the course, one forward and one backward. The light comes either from power lines or small gasoline-driven electric units. Sometimes wind is used to run electric generators or acetylene gas may be used. The airways are under the super-

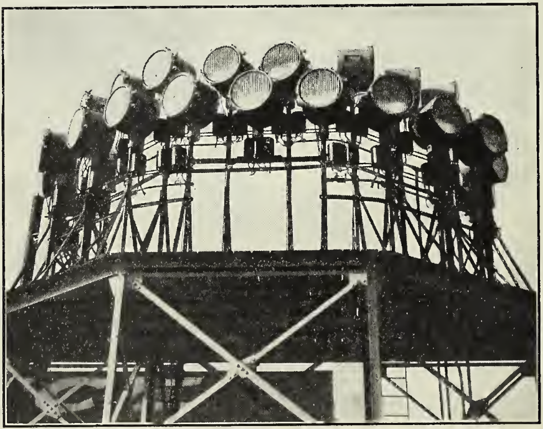


Ewing Galloway

A modern airplane field at night seen from the air. Can you explain the use of the different kinds of lights?

vision of the Government. There have been recently a few very large beacons installed which give directions to aviators for long distances. The best known is the Lindbergh beacon installed on the top of an office building in Chicago, 600 feet above the pavement. This light has two billion candle power, and it is said that on clear nights planes 600 miles away from each other could steer by it from opposite directions.

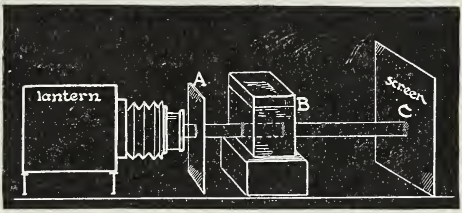
Flood Lighting. During the World War industries used flood lights on a large scale for the first time in history. Forced production then demanded night work, and there was also need of lighting to prevent damage from spies and malcontents. Flood lighting of railroad yards, docks, quarries, and construction areas gave protection to property, greater safety, and more speedy work. Flood lighting is also used for illuminating canals, airplane fields, and other areas where a constant steady but not too strong light is demanded. Another use of flood lighting is to make a beautiful building visible in the evening. Washington Monument and the Capitol building in Washington or the State House of your own state or some building of special interest to tourists may be seen under the strong rays of concealed lights.



Galloway

Landing field flood lights. A battery of lights giving 5,000,000 candle power. Compare with the picture on page 175 and tell how they are used.

Demonstration 2. Penetrating power of red and blue light. Enclose a stereopticon so that a heavy beam of light escapes through two slits in large cardboards set four inches apart in the path of the projection beam so as to get nearly parallel rays. One of these cardboards may be in the slide holder. Set jar so that the beam will pass through it near the middle and strike a white cardboard screen at *C*. Have the room dark. Pour water containing one or two per cent of sodium hyposulphite into the jar. Notice that the white light is seen reflected on the screen. Add 5 cc. concentrated sulphuric acid to each 100 cc. solution in the jar. Watch the changes in the jar and on the screen.

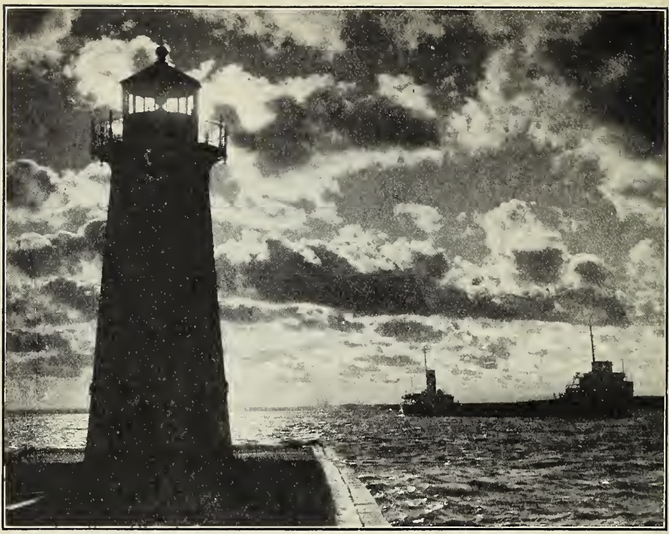


A. 1. How does this change the condition of the liquid in the jar? 2. How does the light spot on the screen change? 3. What is white light composed of? 4. Which can penetrate the obstructing particles better, red or blue?

B. Insert in the beam of light between the lantern and the jar (1) a piece of red glass; (2) a piece of blue glass. What is the result?

Why Red Lights Are Used in Signals. Red light is used because it is found that red has the greatest penetration. Elaborate tests have shown that red light seems to penetrate fog and mist more readily. It may be that the eye is more sensitive to red light than to other colors. At sunset and at sunrise, the rays come through a greater depth of dust-laden and fog-laden air. This absorbs all the rays in white light more easily than it does the red, hence a greater proportion of red reaches us than at mid-day. For the same reason red light is of more value in sending signals through foggy and dusty atmosphere. There is less loss of light and it can be seen from a greater distance than any other color. The tail lights of automobiles make use of red lights, as do all traffic signals. The most economical red light yet devised is in the neon tube. The neon gas is electrified in a rarefied space and produces an orange-red glow which can be seen for long distances.

Use of Lights by Planes. The United States Government demands that planes carry lights just as automobiles do. These lights are side and tail lights which guide other planes at night



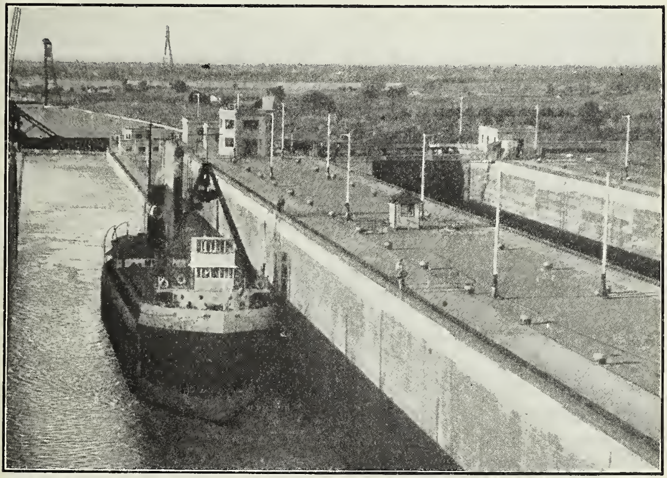
© *A. E. Young, Ewing Galloway*

St. Marys Light marking an entrance to the Soo locks, at Sault Sainte Marie. With what is the boat probably loaded? Give reasons.

when flying in formation. Planes must also have headlights for landing. Cabin planes must be well lighted, and the instrument board, in particular, must have very careful lighting to avoid glare.

Lighthouses. At the time of the organization of the United States government, there were just 10 lighthouses operated by the colonies. Today there are over 20,000 aids to navigation, of which nearly 6000 are lights. We have over 40,500 miles of coast to guard so that these lights and buoys are necessary. Most unlighted aids are buoys and spars, while gas buoys are used to mark channels and dangerous rocks. Lighthouses are usually used to show the entrance to a port or to warn against dangerous reefs or sand bars. An example of the latter use is seen in the lighthouse on Cape Hatteras, which is the tallest in the world, rising 193 feet; although a light on Cape Mendocino in California rises from a cliff 420 feet above the shore. An example of the former is the most powerful light in this country at the entrance to New York harbor on the New Jersey side. The lights themselves are great revolving lens-like housings, inside of which is placed a powerful light. Because of isolation, kerosene lamps are still used, although some lanterns use vaporized gasoline with incandescent mantles. Many automatically controlled beacons burning oil or acetylene gas are used. One of this type in Hawaii has been in continuous use since 1911. There is a gradual change to better lights in progress. In 1933, 153 lamps were changed to electric and 69 to acetylene.

Lighting Ship Canals. The Suez, Panama, and "Soo" canals all have elaborate lighting systems, especially for the locks. The Welland Ship Canal, connecting Lakes Erie and Ontario on the Canadian side, has recently spent $120,000,000 for improving the lights. The lift in the locks is greater than in any other canal. Its entire 24 miles are lighted with modified airport lighting fixtures, and the locks particularly have lighting free from glare, and also have lights placed so as to show the surface of the water and the walls of the locks.



Galloway

A lock on the Welland Canal. Notice the lighting fixtures. These locks can be used safely both night and day. This is part of the new Great Lakes Waterway, which when completed will admit ocean-going steamers to the Great Lakes.

Searchlights. The strong beams of light used by battleships are made possible through reflection by concave mirrors rather than by lenses. When light is placed at the principal focal point of a mirror, of a special form, the reflected rays go off in a parallel beam, and because of this it may be seen at a great distance. The same type of mirror is used in locomotives and automobile headlights.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

buoys
horizontal
beacons
green
blue
red
white
top
routes
concave
special
fog
acetylene
kerosene
flashing
dangers
electricity
harbors
parallel
side

Airplane (1)____ show air (2)____, while lighthouses show (3)____ or entrances to (4)____. The danger light is (5)____ because it can be seen for greater distances through (6)____ or dust. Planes have (7)____ lights in addition to head and tail lights. Lighthouses may have a fixed or a (8)____ light. The better lights now use (9)____ or burn (10)____. Searchlights give a strong beam of nearly (11)____ rays of light because of the use of a (12)____ mirror.

PROBLEM TEST

Each introductory phrase below is followed by six words or phrases. Five of them relate to the idea expressed in the introductory phrase. In each case state (1) *the* principles involved *and* (2) its use or effect. *Cross out the one which does not fit in with the group.*

I. *The Airplane Beacon*

1. air routes
2. beams of light
3. whistling buoys
4. government supervision
5. white or colored lights
6. fixed or flashing light

II. *A Red Light*

1. tail light
2. blue light
3. neon light
4. dust in air
5. danger sign
6. fog or mist

III. *Lighthouses*

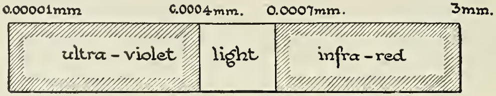
1. sandbars or reefs
2. aid to navigation
3. harbor channel
4. flood lighting
5. beams of light
6. revolving lights

PROBLEM IV. WHAT INVISIBLE RADIATIONS ARE USEFUL TO MAN?

Reception of heat and light from the sun is such an everyday occurrence that we think little about it. We are told, however, that space is just full of radiations other than those which produce heat and light. Some use the term "invisible light" for the radiations that do not affect the eye. The invisible radiations are greatly in excess of those which are visible.

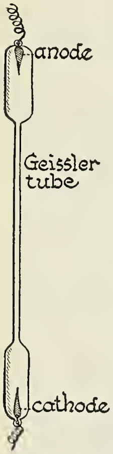
Origin of Radiant Energy. The molecules in all matter are believed to be in vibration. The degree of heat or temperature of a body determines the energy of vibration. All vibrating molecules are centers of radiation. The walls of the room radiate heat to us; we radiate heat to the walls. When energy is added to an iron rod by holding one end in the fire, greater vibration energy results in the molecules and they soon radiate light waves. The difference between heat and light waves is merely one of vibration rate or frequency. All radiant energy travels at the same speed, 186,000 miles per second. Hence the different rays, if of wave form, must differ in wavelength because wavelength times frequency equals speed or velocity.

Invisible Radiations. Scientists have found that light makes up a very small part of the total radiation spectrum. Outside of light the invisible radiations are important in several fields, particularly the heat rays, X rays, ultra-violet rays, and radio rays. These all travel through space just as light does, but they vary in their ability to penetrate matter.



How much of this area do we see? How much do we feel?

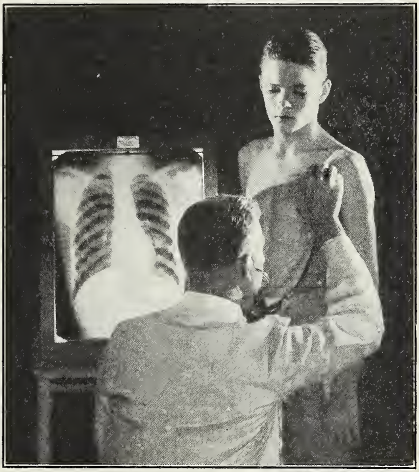
Electrical Discharge in Vacuum Tubes. A vacuum tube having metal contacts called electrodes sealed through the end is joined to a source of electricity of fairly high voltage. When this is done, a discharge takes place, and in a darkened room this discharge gives out a glow of light. That electrode connected to the negative pole of the battery is called the *cathode* and the one connected with the positive pole is called the *anode*. The rays given off from the cathode are really a stream of electrons shot off with possibly half the speed of light. Where they strike the walls of the glass bulb, they produce a greenish-yellow light. The value of the cathode rays comes from the fact that they can be converted into X rays.



Electrical discharges make a glow in this tube.

X Rays. One of the most important discoveries of the last century was that of the X rays. They were discovered quite by accident by a German scientist, Roentgen, in 1895 when experimenting with the cathode rays. The great value of the rays lies in the fact they will act upon photographic plates just as light does and that they will penetrate almost all substances. The rays do not pass through all substances with equal ease. They pass through the flesh better than through bones; they pass through bones better than they do through gold or iron; and they pass through gold or iron better than they do through lead. It is because of this difference in absorption of the rays that shadow pictures can be obtained to show if bones are broken, the location of a bullet in the body or metal objects swallowed, and other conditions within the human body. Pus pockets which indicate ulcers show up around the roots of diseased teeth. The medical and surgical use of the X ray is probably the most important, but by its help jewelers can tell true from false gems; customs officials can easily detect many forms of smuggling; and in industrial plants flaws in castings can be discovered.

The X rays are not visible, but when they fall upon certain chemical substances, they produce a phosphorescent light which is visible to the human eye. A device called a fluoroscope has a screen coated with one of these substances. The light between the screen and the eyes is shut off. With this one can observe directly without the trouble of making the X-ray pictures.



Eastman Kodak Company

An X ray has been taken of this boy's chest and now the physician is listening to the chest sounds through a stethoscope. It is by such means that the presence of tuberculosis germs in the lungs are discovered.

Infra-Red Rays. The invisible infra-red rays, as we know, produce heat, but they have other properties of which scientists are learning that may be of great value. It has been found that the infra-red rays penetrate the flesh deeper than the red rays of light do. They are being used on that account for the treatment of lumbago, neuritis, neuralgia, and rheumatism. Experiments indicate that infra-red rays just under the visible red penetrate the skin and are beneficial in warming the blood. Just as there are chemicals sensitive to light, there are other chemicals sensitive to infra-red rays. Plates coated with infra-red sensitive chemicals can be used to take photographs at night or in a dark room where no light is present. These plates also have the advantage over ordinary photographic films or plates by taking distant landscape pictures. The fine dust in the air that absorbs the shorter light waves has little effect on the infra-red rays.

Ultra-Violet Rays. Nearly half of the radiation from the sun is visible light, but over half of it consists of the infra-red and ultra-violet rays. Our ordinary tungsten lamps give back only about four per cent of the electrical energy as light, practically no ultra-violet rays, but an excess of heat. "Sun lamps" are now manufactured that will give an abundance of both infra-red and ultra-violet rays. By means of filters and special glass, the rays can be kept within the limits that are considered beneficial to health.

Eastman Kodak Company

This picture was taken by the infra-red light given off by two electric irons heated as one would use them to iron with. Plates sensitive to the infra-red rays were used.

The ultra-violet rays are among the most important because they aid greatly in certain chemical changes. They help put the carbon in the air back into plants in the process of photosynthesis and so make possible a continual production of food. They help the photographer but are harmful when allowed to shine into one's eyes. There are certain salts which are white in ordinary light but which show fluorescent light in colors under the action of the ultra-violet rays. An interesting use of this is made in the Franklin Institute Museum, Philadelphia. You enter a room in daylight that has plain walls, but when the light is changed to ultra-violet rays, colored paintings appear. The use of fluorescent pigments makes this possible.

Uses of the Ultra-Violet Ray in Industry. The ultra-violet radiations have the following uses in industry:

1. Tests made by ultra-violet radiations for durability of paints, fastness of color in dyes, etc. This usage is decreasing and is not very important.

2. Certain minerals have the property of fluorescence. They become lighted under the influence of the ultra-violet rays. Old paintings, manuscript, etc., may be examined by the ultra-violet rays to see if one has been superimposed on another.

3. Ultra-violet rays are used in photo-chemical treatment of patent leather, in drying, and in the toasting process of certain tobaccos.

4. A few years ago it was expected that the sterilization property of the ultra-violet rays could be used in industry, and many swimming pools have been equipped with such apparatus. The ultra-violet ray is not as useful as it was expected because it penetrates such a short distance into most substances. They would have to be passed under the rays in such thin sheets that the process of sterilization would be too expensive. It has had limited use in sterilizing food products, but there are other more practical ways of doing this on an industrial scale.

5. The largest use of the ultra-violet ray is in the production of vitamin D through irradiation of certain substances. Researches show that vitamin D in codliver oil and other substances aids in the formation of bones and keeps people healthy. Ultra-violet rays have been used effectively to combat the disease called rickets, hence it seems that the body under certain conditions can make its own vitamin D, probably in the deeper layers of the skin. The reason why sunlight is so useful is because the sun's rays act upon a fatty substance in the body called ergosterol. If this substance is treated with the ultra-violet radiations, it becomes able to make vitamin D. The best way to combat rickets, however, is by giving the patient large doses of concentrated vitamin D. In this country some of the great cereal companies treat certain of their cereal products with ultra-violet rays so as to produce vitamin D. Codliver oil, yeast, and other products are being irradiated, while in England milk cows in certain dairies are being treated to increase vitamin D in their milk. An experiment with 180 chickens at Concordia, Missouri, showed that one lot of 90 treated with ultra-violet rays for two hours each morning gave 158 eggs, but the untreated lot of 90 chickens gave only 126 eggs in the same time. This use of the ultra-violet ray seems to have commercial possibilities.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

cosmic
radio
infra-red
ultra-violet
sight
anode
film
plate
cathode
light
spectrum
colors
rays
energy
practice
yellow
industry
vibrations
vacuum
electrons

The band of waves known as (1)____ make up a very small part of the whole (2)____ of radiant (3)____. High-voltage electricity when passed through a (4)____ tube may produce a stream of (5)____ from the cathode. When these strike the walls, a greenish (6)____ light known as (7)____ rays result. When cathode (8)____ strike the metal (9)____ pole in an X-ray tube, (10)____ rays are produced. Heat rays or (11)____ rays have less frequency of (12)____ than light waves. Ultra-violet waves have many uses in nature, as in starch making in plants in (13)____ and in medical (14)____.

PROBLEM TEST

Each introductory phrase below is followed by six words or phrases. Five of them relate directly to the idea expressed in the introductory phrase. In each case state (1) *the* principles involved *and* (2) its use or effect. *Cross out the one which does not fit in with the group.*

I. *The X Rays*

1. fluoroscope
2. spectroscope
3. Roentgen
4. tooth ulcers
5. Coolidge tube
6. cathode rays

II. *Infra-Red Rays*

1. health
2. dust
3. invisible
4. photography
5. visible
6. heat

III. *Ultra-Violet Rays*

1. radiations
2. health
3. light
4. vitamins
5. photography
6. photosynthesis

◆

REVIEW SUMMARY

In preparing this review summary bear in mind its purpose. It is to be a guide in assisting you in giving a talk on any of the topics covered in the unit. This may suggest to you that you need not only the main generalizations and principles, but a good deal of the detailed matter as filling.

1. Combined natural and artificial illumination is frequently required in efficient industrial management.
2. The production of images by lenses increases the range of human vision.
3. Light is a much-used agent of guidance for transportation.
4. Light covers but a small part of the spectrum of radiant energy.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write number of untrue statements. Your grade = right answers* $\times\ 3\frac{1}{3}$.

I. **In schools and factories:** (1) the intensity of light in daytime is greater near windows; (2) there is glare if one faces the window; (3) if the room is large, the lighting is more even; (4) artificial light is always necessary; (5) part artificial and part natural light are often best.

II. **When taking portraits one requires:** (6) a strong white light directly in front of the person; (7) strong daylight coming to one side; (8) one side of face lighted more strongly than the other; (9) a white cloth screen to reflect a single side light; (10) lighting all the regular room lights.

III. **A double convex lens will produce a real image when the object is placed:** (11) between the lens and the principal focus; (12) at the principal focus; (13) between F and 2 F; (14) at a point equal to twice the focal length of the lens; (15) beyond 2 F.

IV. **Ultra-violet rays are:** (16) the shortest waves the eye can detect; (17) invisible; (18) transmitted through quartz glass better than through ordinary window glass; (19) helpful in preventing rickets; (20) heat-producing rays.

V. **X rays:** (21) are forms of radiant energy; (22) can be seen in a dark room; (23) will penetrate opaque solids; (24) cannot be produced without electricity; (25) will pass through one substance just as well as any other.

VI. **A "sun lamp" for health treatment should:** (26) give only ultra-violet rays; (27) give all the infra-red rays; (28) give all the X rays; (29) give certain ultra-violet and infra-red rays; (30) give a mixture of heat, light, ultra-violet, and X rays.

PRACTICAL PROBLEMS

1. You are reading by daylight in a north room in winter and use a reading glass. Tell all the changes through which the rays of light pass from the time they leave the sun until they give you the sensation of light in your brain.
2. Explain how it is possible to use a glass lens to start a fire.
3. Does a person with two eyes have an advantage over a person with one eye? If so, what? Explain. Are field glasses with two eyepieces any better than a spyglass with one eyepiece if the two have the same magnifying power?
4. Why is it a good plan for people over thirty years of age to have their teeth X-rayed at least every five years?
5. Why should exposure to radiations from sun lamps be taken only under medical direction?
6. Can you explain to your parents the difference between the reflecting and the refracting telescopes so that they will understand the way the two telescopes work?

INTERESTING THINGS TO READ ABOUT

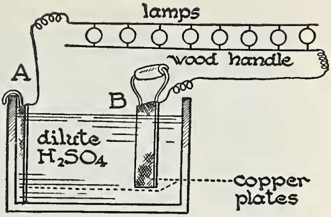
1. The history of spectacles.
2. Story of the casting of the 200-inch reflector.
3. Use of the periscope in industrial laboratories.
4. The largest and the smallest electric lamps.
5. Radiations from the arc lamp.

LEISURE TIME ACTIVITIES

1. **Semaphore Signals.** Learn from a signal-tower operator what the different combinations of signals used along the rail track mean.

2. **A Footlight Dimmer.** The diagram on page 189 shows how you can put a very dilute acid into the circuit. *A* is fixed to one side of the jar. By moving *B* toward *A* the lights brighten; when moved

back, they get dimmer. Do not touch any bare connections or the copper plates with bare hands when the current is on. Weaken or strengthen the acid solution to fit your individual needs.



3. **Miniature Stage Lighting.** Plan a miniature stage for puppet plays. Devise ways of producing good lighting effects for actual use.

4. **Home Portraiture.** Devise how you can best fit up a home studio for your own use.

5. **Are Your Fingers Transparent?** Hold your hand in front of a lighted 100-watt lamp, fingers close together. Look toward your hand. Why do you see red light through the edges of the fingers?

6. **Images with Lenses.** Use a reading glass to see if you can produce images on a screen both larger and smaller than the object.

SCIENCE CLUB ACTIVITIES

1. **A Stereoscope Meeting.** Try to get a collection of stereoscope pictures and a number of stereoscopes. You will enjoy seeing pictures through this instrument.

2. **How the Stereopticon Produces a Large Picture.** Have someone demonstrate a simple stereopticon and show a set of slides with it. Demonstrate a film slide lantern also if available.

3. **Signal Lights.** Members prepare a list of all types and kinds of signal lights they have seen or read about and report upon them.

4. **X rays.** If possible, induce a friend of some member of the club to invite the club to his X-ray studio or to bring a portable machine to the club meeting. He will demonstrate and explain just how the X ray is produced and will tell you what it will do.

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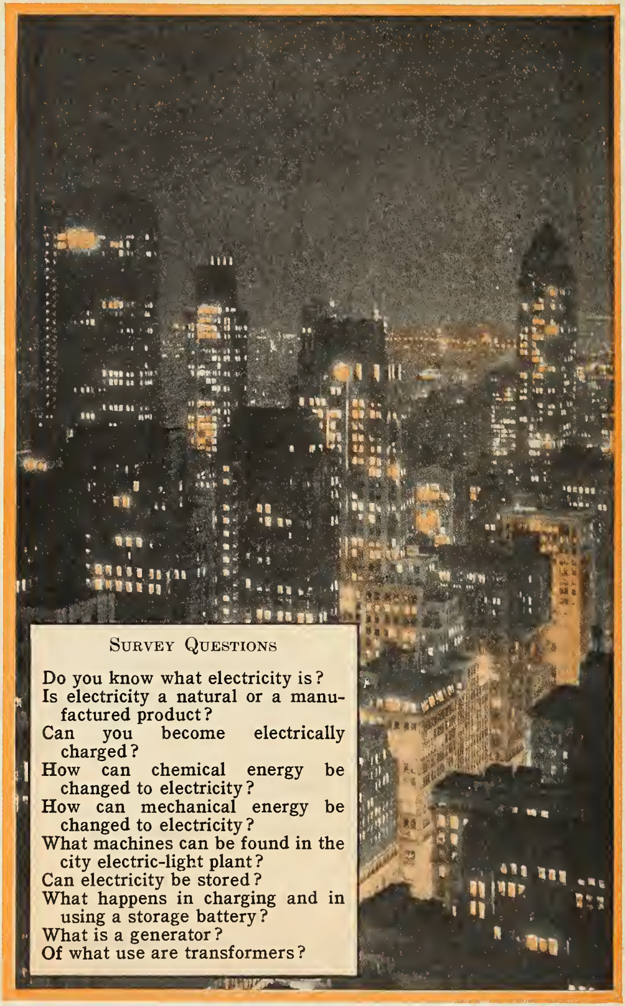


SURVEY QUESTIONS

Do you know what electricity is?
Is electricity a natural or a manufactured product?
Can you become electrically charged?
How can chemical energy be changed to electricity?
How can mechanical energy be changed to electricity?
What machines can be found in the city electric-light plant?
Can electricity be stored?
What happens in charging and in using a storage battery?
What is a generator?
Of what use are transformers?

R. I. Nesmith and Associates

UNIT VII

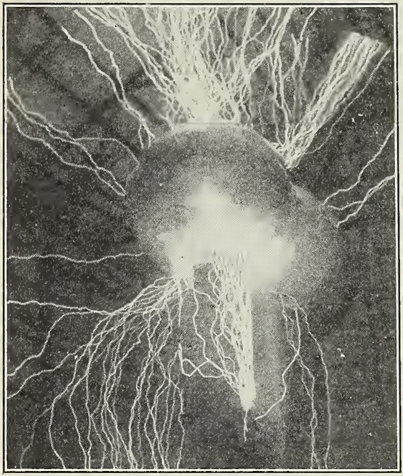
HOW ELECTRICITY IS PRODUCED AND SOLD

PREVIEW

Nature is slow to give up her secrets. It is only by constantly keeping at it that the scientist has been able to give us a fuller knowledge of what electricity is. Twenty-five years ago there was a common saying, "We do not know what electricity is, but we do know many things that it will do." That saying is not true today because the last twenty-five years of science research has disclosed more facts about the nature of electricity than did the preceding 2500 years.

Modern scientists tell us that matter itself is built up out of electricity and consequently all you are is a bundle of highly organized groups of particles of electricity. How this is possible may be made clearer as we study a little more in detail the nature of electricity. We have already found out some things about it. We know that it flows much as a current of water. We know that it can be produced by friction, and that it makes a magnetic field which causes the movement of the compass needle or other magnets brought within that field. We know also that Volta discovered that it could be chemically produced. But what about manifestations of the great power of electricity?

If you were to visit the new laboratory of the California Institute of Technology at Pasadena, you might be shown the artificial lightning flash that physicists have made with their new electrical devices. Electricity having a pressure of from 5,000,000 to 10,000,000 volts is released in that building with a crash that resembles a small thunder clap. But when we realize that a flash of real lightning may have a pressure of 100,000,000 volts, we can see that we have not yet full control of the elements. It is important to be able to produce currents of high voltage, because the higher the voltage, the greater distance it can be sent without waste. We cannot increase the pressure enough by ordinary means of manufacture, so we use an instrument called a transformer. You may have seen huge transformer stations on power lines in California, at Niagara Falls, or other places where electricity is sent hundreds of miles from great stations where water power is plentiful to the cities where it is used. In these transformers the current is changed to a higher voltage or "stepped up" for its long journey over the wires, and "stepped down" again for use in the homes and factories. The pages which follow will help us to understand more about the nature of electricity, how it is manufactured, how it is transported, and how it is finally transformed to a voltage safe for our own homes.



Mass. Institute of Technology

7,000,000 volts of artificial lightning — produced by the Van de Graaff electrostatic generator at the Round Hill laboratory of the Massachusetts Institute of Technology.

Before beginning a detailed study of this unit, try to recall the principles and generalizations that you have learned in your previous study of the subject. Some of these principles and generalizations are the following:

1. Soft iron is best for electromagnet cores and steel or some steel alloy for permanent magnets.
2. Every wire carrying an electric current is surrounded by lines of magnetic force.
3. Magnets are surrounded by lines of magnetic force which are assumed to come out of the north and to enter the south poles.
4. A magnetic pole attracts iron and steel and other unlike magnetic poles.

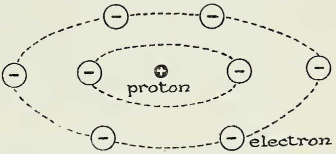
5. Opening the circuit of an electromagnet destroys its magnetic field.

6. Continuous motion may be produced by properly controlled electric current in electromagnets.

PROBLEM I. WHAT IS ELECTRICITY?

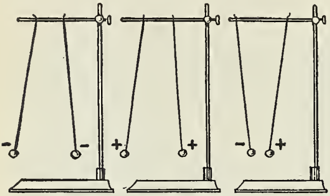
Composition of Matter. In this problem let us bring together some of the things we have already learned about electricity and try to apply them to a better understanding of how electricity is used today. We have read that matter is composed of tiny particles called molecules, and that these in turn are made up of still smaller particles called atoms. Even with the strongest microscope we cannot see a molecule, for it would have to be 1000 times its present size to be visible. If the grains of sand in a pile containing a cubic mile of sand could be counted, there would be just about as many sand grains as there are atoms in about ten large drops of water.

How an Atom Is Constructed. Each atom has a central nucleus which contains one or more particles called protons. Each of these protons carries a positive charge of electricity. Revolving around this central nucleus in definite orbits are negatively charged particles called electrons. These electrons move in definite orbits around the central nucleus much as the planets move around the sun. Some believe the nucleus contains not only the free protons but some protons which are combined with electrons making new neutral bodies called *neutrons.* It is possible according to this theory for the nucleus to contain both neutrons and protons.



An atom showing protons and electrons. Where would the neutron be found, if present?

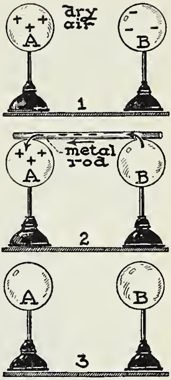
Electric Charges. When an atom contains an equal number of protons and negative electrons, it is said to be neutral. When two neutral bodies such as glass and silk are rubbed together, some of the electrons leave the atoms of one of the bodies (the glass) and enter the other body (the silk). The body that loses electrons has more protons (positive electricity) than electrons and is said to be positively charged. The body that has an excess of electrons is negatively charged. Protons can never leave the atom, but electrons can pass off from it to another body. Protons and electrons attract each other. A negatively charged body attracts a positively charged body because of the excess of electrons on one body and the unsatisfied protons in the other. Two bodies having the same charges repel each other because protons repel protons and electrons repel electrons. The law of electrical attraction and repulsion is this: *Like charges repel each other; unlike charges attract each other, and either charge attracts a neutral body.*



What law does this diagram illustrate?

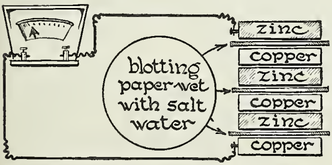
How a Body May Become Charged. What we have just read will explain the experiment which we tried in the seventh grade with frictional electricity. When hard rubber is rubbed with fur, the rubber receives electrons from the fur. Since the hard rubber has an excess of electrons, we say it has a negative charge. The fur having an excess of protons is said to have a positive charge. If a neutral pith ball is touched with the charged rod, some of the electrons will be pushed off into the ball because electrons always repel each other. The pith ball then has a negative charge. If the negatively charged rod is now brought near the negatively charged pith ball, it will be repelled, showing that like charges repel each other. Glass rubbed with silk becomes positively charged. It will charge a neutral pith ball positively if it touches it because electrons will leave the pith ball and enter the glass. The positive glass will repel the positive pith ball and attract a negatively charged ball.

Current Electricity. If we have two insulated conductors *A* and *B*, and we give *A* a positive (+) charge and *B* a negative (−) charge, they will keep their charges a long time if separated by dry air but will rapidly lose them in moist air. If a metal rod is brought into contact with the two equally charged bodies, they will be discharged. What happens is this: *A* lacks electrons while *B* has an excess of electrons. The metal rod serves as a bridge across which the electrons may pass from B to A and thus make both bodies neutral. This flow of electrons along a conductor is what we call a *current of electricity* or electricity in motion in contrast to electricity at rest or *static electricity,* which is the name applied to electricity on a charged body. We can never hope to see an electric current because the electrons are so small.



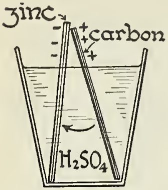
What is an electric current?

The Early Beginnings of Current Electricity. An Italian professor of anatomy named Galvani was one day working with a machine for generating electricity by friction. It chanced that near by were some frogs' legs taken from freshly killed frogs. When his assistant's knife happened to touch the frog's leg and the electrical machine, the frog's leg twitched. This incident set Galvani to experimenting to see what it was that caused the twitching of the legs. After a time he found that when the frog's legs were touched by two unlike metals which were linked together, the legs twitched. These experiments of Galvani paved the way for Volta, another Italian, who found that three things were necessary to have the frog's legs twitch: copper, iron (or two unlike metals), and the fluid within the muscle. He believed that there was some chemical action going on which was brought about by the combination of these three substances. He went on experimenting with different substances to find out what would cause electricity to flow from them, and as a result produced the so-called Voltaic pile, the first simple cell which produced electricity from chemical energy. In this cell, plates of copper and plates of zinc were separated by layers of cloth wet with salt or acid, and as a result electrons moved from one metal to the other, giving one a positive and the other a negative charge. When the two end metals were connected with a conducting wire, electrons



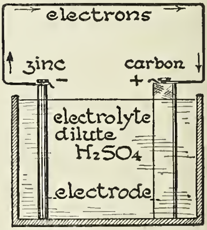
A simple voltaic cell, such as Volta made.

passed from the negatively charged metal to the positively charged metal. This was the first continuous flow of current electricity produced in the world.



A simple wet cell. What action takes place here?

A Simple Chemical Cell. When rods of zinc and carbon are put into a dilute solution of sulphuric acid and the ends of the rods not covered by the solution touch, an interesting thing happens. A current of electricity flows from the zinc to the carbon outside the liquid. The carbon and zinc are called electrodes and the sulphuric acid is called the electrolyte. By means of chemical action, electrons are taken from the carbon in the liquid and passed on to the zinc. This gives the zinc a negative charge and the carbon a positive charge. This is called a wet cell. In the commercial unit cell ammonium chloride would be used for the electrolyte in place of the sulphuric acid shown in the diagram. The acid is too active for efficient use. If a coil of wire or other conductor be used to connect the ends of the carbon and zinc, electrons pass through the wire and we have a flow of electricity. If the current passes through electric devices such as a bell or buzzer, the current does work, causing the bell to ring.

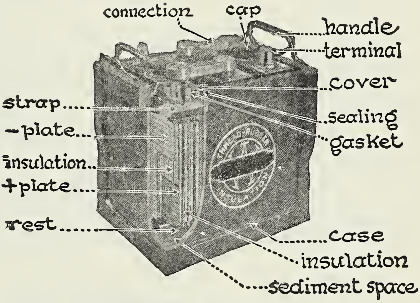


A chemical cell. Where is this device used? For what purposes?

The Common Dry Cell. In the dry cell the zinc is the outside metal container and the carbon is a large rod in the center. Between these are the chemicals. A paste of ammonium chloride is placed next the zinc, and a layer of manganese dioxide is around the carbon. There is chemical action between the ammonium chloride and the zinc. The manganese dioxide supplies oxygen to remove the hydrogen that collects on the carbon. If hydrogen is allowed to collect on the carbon, it decreases the current temporarily.

Storage Batteries. This name is misleading because it is impossible to *store* electricity with a "storage battery." We can pass an electric current through a storage battery and produce chemical changes which, when we stop charging, will *reverse* themselves and in doing so will produce another electric current. This is one more illustration of the transformation of energy. The storage battery has not stored electricity, it has stored chemical energy capable of being transformed into electricity. Of the two types of storage cells — the lead cell and the alkaline cell — the lead cell is much cheaper and the one more widely used.

The Lead Storage Cell. Each positive plate is lead peroxide and the negative is lead. The substance which produces chemical action and causes the current is dilute sulphuric acid (1 part acid to 2 parts water by weight). When the battery is working, the positive lead peroxide loses oxygen and becomes lead, while the negative lead becomes oxidized. When the battery is being charged, lead peroxide is being increased on the positive plate, and pure lead on the negative plate. In charging, electrical energy produces chemical action in the battery. When the battery is in use, a reverse chemical action produces an electric current.



A three-cell lead storage battery. Why is a sheet of insulating material used between each pair of plates?

Testing the Storage Battery. One practical thing we can learn to do is to test our automobile storage batteries. The usual method of testing the condition of the battery is to determine the specific gravity of the acid solution. It is tested with an instrument called the hydrometer. The hydrometer scale is based upon pure water as 1000. A fully charged battery shows by hydrometer test 1280 to 1300; half charged is 1215, and discharged is 1140. It is better never to let the battery charge get low, keep it from three fourths to fully charged. The plates must be kept covered with liquid by adding distilled water or rain water at intervals. If the battery is idle, it should be charged every two weeks.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange these in proper numerical order. The same word may be used more than once.

energy
molecules
acids
current
Volta
advance
electrolyte
reverse
electricity
still
move
electric
understanding
machines
knowledge
protons
neutrons
conductor
neutral
electrons
solution
chemical
numbers
Franklin
experimenting
studying
matter
rocks

Atoms of (1)____ are composed of the smallest things we know about, namely, protons and (2)____. When these are present in equal (3)____, the matter is (4)____; but if there is an excess of (5)____, it is positive, and if an excess of (6)____, it is negative. When electrons (7)____ along any (8)____, they produce a (9)____ of (10)____. Galvani and (11)____ did the early (12)____ which led to an (13)____ of (14)____ electricity. When a storage battery is being charged, a (15)____ change is produced by the charging current. When the battery is being used, a (16)____ chemical change produces an (17)____ (18)——.

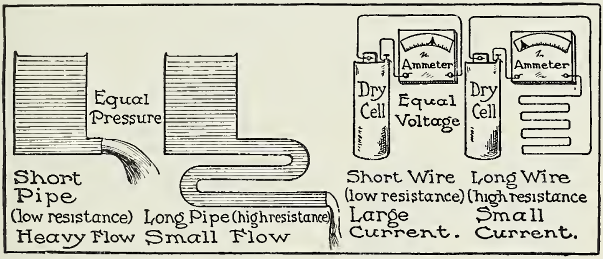
PROBLEM TEST

Check those statements listed below which express facts or principles we must use in the production of a current of electricity from chemical action

1. Water is a good solvent.
2. Electrons but not protons can move from glass to silk.
3. The reaction of a given electrolyte upon different elements is not the same.
4. Insulators prevent the flow of electrons.
5. In a dry cell one pole is electrified positively and the other negatively.
6. An electric current cannot be seen.
7. Electrons travel from a negative body to a positive body when joined by a conductor.
8. A frog's leg is a substitute for a chemical cell.
9. When a body has an equal number of electrons and protons it is a neutral.
10. The storage battery uses sulphuric acid for the electrolyte.

PROBLEM II. HOW ELECTRICITY IS MEASURED

Wire Resistance to Electricity. There are many likenesses between the flow of water and the flow of electricity. A tank of water can be emptied more quickly with a short pipe than with a long one of the same diameter because the long pipe has more surface to rub against the flowing water, and produces greater friction, thus allowing less water to get out in a given time. There is a very close parallel to this in the case of electricity passing through wires. If you connect the poles of one cell with a long wire, and the poles of another cell with a short wire of the same kind and the same diameter, more electricity will be discharged per second through the short than through the long wire. The reason for this is that the longer wire offers greater resistance to the current, so that less current flows, but as in the case of the tank of water, the current will flow for a longer time.

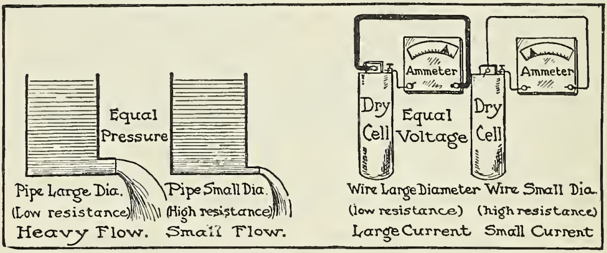

Equal Pressure
Short Pipe
(low resistance)
Heavy Flow
Long Pipe (high resistance)
Small Flow
Ammeter
Ammeter
Dry Cell
Equal Voltage
Dry Cell
Short Wire
(low resistance)
Large Current.
Long Wire
(high resistance
Small Current.

Explain, with the help of your text, the analogy between water flow in a long and short pipe and electricity in a long and a short wire.

A pipe of large diameter will empty a tank of water much quicker than one of small diameter because it carries a larger volume of water than the smaller one. Just so with electric currents. The wire with a large diameter permits a larger flow of electricity than one of small diameter.

Electric Pressure. Suppose you have two tanks of water, one holding a large amount and the other a small amount, and the water in them is kept at the same level. The water running from the faucets at the bottom will have the same pressure just as long as the level is maintained evenly in the two, and if the openings of the two faucets are of the same size, equal streams or currents of water will flow from them. The electrical pressure (called *voltage*) is independent of the size of the cells used. The cell of a small flashlight may have just as high voltage as does a common dry cell which has a pressure of about 1.5 volts. A lead storage cell will give 2 volts while an automobile battery of three cells will give 6 volts. A *volt* is the unit used in measuring electric pressure, or the force which causes electricity to flow through a conductor. An instrument for measuring voltage is called a *voltmeter*.

Electric Current. Water pressure alone will not tell us how great a flow may be obtained from a tank. The size and length of the pipe help to determine this, because they regulate the resistance and resistance is one factor which determines the amount of water which flows. This holds also in a similar manner with electricity.

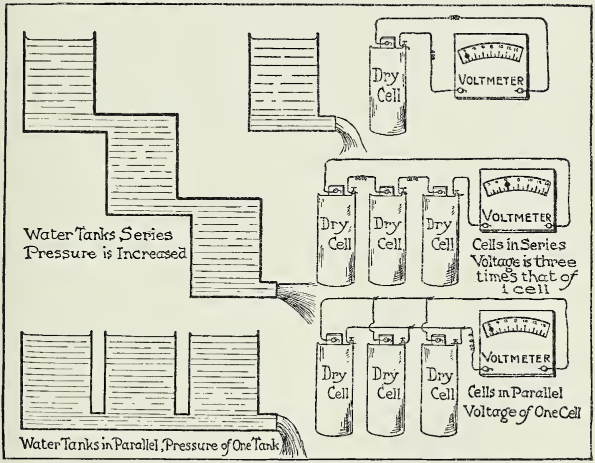

Equal Pressure
Pipe Large Dia.
(Low resistance)
Heavy Flow.
Pipe Small Dia.
(High resistance)
Small Flow.
Ammeter
Ammeter
Dry Cell
Equal Voltage
Dry Cell
Wire Large Diameter
(low resistance)
Large Current
Wire Small Dia.
(high resistance)
Small Current

Explain the analogy of water flow in pipes of large and of small diameters and electricity in large and small wires.

If we have the poles of a cell connected by a wire of small resistance, a large current will flow through it, but if the resistance is great, a small current will flow. The unit for measuring an electric current is the ampere, so named after the French scientist, Ampère. The instrument by which this current is measured is the *ammeter*.

How to Join Cells for Use in the Home. There are two ways in which we may join cells together so that we can overcome the resistance in any circuit. These are in *series* and in *parallel*. We can understand these terms best by referring again to our water tanks. Suppose we have three tanks of water at the same pressure, and connect them so as to get a water column three times as deep as that of a single tank. The water pressure will be three times that of a single tank. If we join three cells *in series*, that is, zinc to carbon, and connect a voltmeter in the circuit, we shall find three times as much pressure recorded as when a single cell is attached to the voltmeter. A high pressure (high voltage) will give us a larger current (in amperes) through the bell, motor, or light than we can get from the low pressure. When long wires are used in connecting an electric bell, greater voltage is required to overcome the resistance of the long wire. This increased voltage can be obtained by putting in one or two more cells joined in series. A bell can be made to ring louder and a motor to run faster by this same method.

When we join our three tanks of water at the same level, we increase the capacity to furnish a current of water, although it has no greater pressure than the single tank. We may join three cells *in parallel* by connecting all the zinc poles to one wire and all the carbon poles to another wire, and then join these two wires where we wish to use the current. If we attach a single cell to the voltmeter and read the voltage, and then later attach three


Dry Cell
VOLTMETER
Dry Cell
Dry Cell
Dry Cell
VOLTMETER
Water Tanks Series
Pressure is Increased
Cells in Series
Voltage is three times that of 1 cell
Dry Cell
Dry Cell
Dry Cell
VOLTMETER
Cells in Parallel
Voltage of One Cell
Water Tanks in Parallel, Pressure of One Tank

Explain this water analogy to illustrate joining cells in series and in parallel.

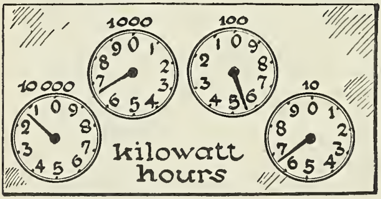
cells joined in parallel to the voltmeter and read the voltage, we find it to be the same. Any number of cells joined in parallel have just the same voltage as a single cell. With the same size of opening for the single and the triple water tanks the water would flow from the triple tank for a longer time. It has a larger reservoir. Thus with the cells joined in parallel, if the voltage of one cell gives all the pressure you need, you can get much longer service from several cells joined in parallel than you can from one cell. These explanations should serve to make it possible for you to use the batteries in your own home intelligently.

Measuring Electricity. Everybody should learn to read the dials on the ordinary electric meter which is part of the equipment of every home that takes its electricity from the city supply. The meter is called the kilowatt-hour meter, and keeps a record of the electric power used. The *watt* is the unit by which we measure electrical power. One watt of power is produced when a pressure of one volt sends one ampere through a wire.

$$\text{Electric power} = \text{watts} = \text{volts} \times \text{amperes}$$

One thousand watts make one *kilowatt* and one kilowatt used for one hour equals one *kilowatt hour*. We buy electricity at so much per kilowatt hour.

How to Read an Electric Meter. A study of the diagram shows that of the four dials, the one to the left moves the least, while the one to the right moves the fastest. The four dials indicate thousands, hundreds, tens, and units. If the thousands' hand is between 1 and 2, it will indicate 1000; if the hundreds' hand is between 6 and 7, it indicates 600; if the tens' hand is between 5 and 6, that will be 50; and the units' hand between 6 and 7 is read 6, making a total of 1656 kilowatt hours. If the previous reading was 1610, then 46 kilowatt hours have been used since the meter was last read. At the rate of ten cents



Dials of a kilowatt-hour meter. Can you read them correctly?

per kilowatt hour, what would the bill be? If your home is equipped with electricity, you will be interested to compare the readings on the bills sent out by the supply company with your own readings of the kilowatt-hour meter.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

kilometer
second
hour
pressure
current
parallel
kilowatt-hour meter
volt
ampere
watt
voltage
series
greater
less
kilowatt
amperes
watts
power
volts
voltmeter

The resistance to an electric current is (1)____ in a long than in a short wire and (2)____ in a wire of large diameter than in one of small diameter. The unit in which electrical pressure is measured is the (3)____; the unit of the current strength is the (4)____. If we join two cells in (5)____, the (6)____ will equal the sum of the two. The voltage of two cells is the same as that of a single cell if they are joined in (7)____. The electricity we buy is measured with a (8)____, and we pay for it at so much per (9)____ (10)____. The unit of electrical power is the (11)____ and is equal to (12)____ × (13)____.

PROBLEM TEST

Check the statements, facts, or principles in the list given below that affect the amount of electric power delivered.

1. The smaller the conducting wire the less the current.
2. The longer the conducting wire the less the current.
3. The size of the wire does not change the voltage.
4. The longer you rub fur and rubber the more electricity you produce.
5. Connecting cells in parallel gives the same current for a longer time.
6. Connecting cells in series increases the voltage.
7. Watts equal volts × amperes.
8. An increase of amperes in a given circuit means a greater loss from heating.
9. We purchase electricity by the kilowatt hour.
10. The watt is the unit of electrical power.

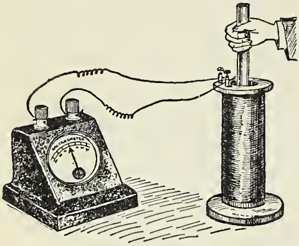
PROBLEM III. HOW IS ELECTRICITY GENERATED, DISTRIBUTED, AND USED?

How Electricity Is Produced. We have seen that electricity can be generated by friction and by chemical action, but this is not the way in which we get most of our commercial electricity. Water power is harnessed to turn turbines which in turn make generators produce electricity, or if water power is not abundant, then coal or oil may be used to produce steam which in turn moves the generators.

Demonstration 1. To See How an Electric Current Is Produced.

Take a coil of wire and connect the ends of the wire with a galvanometer, thus making a closed coil. Move a magnet in line with the axis of the coil down into the coil. Quickly withdraw the magnet. What happens to the needle of the galvanometer? Hold the magnet inside the coil. What is the result?

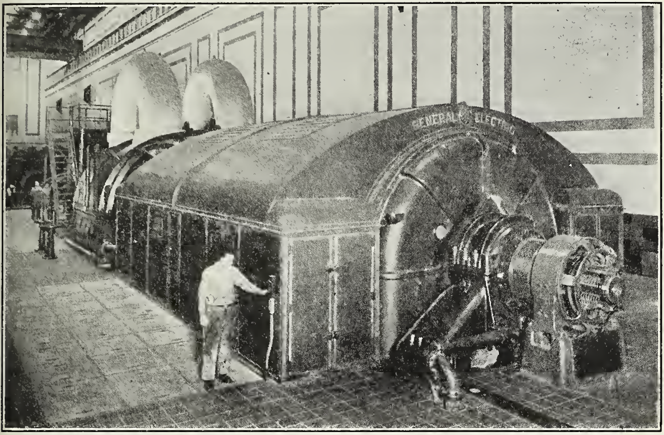
The movement of the galvanometer needle is evidently due to a current of electricity. Under what conditions of coil and magnet does a current result in the coil?



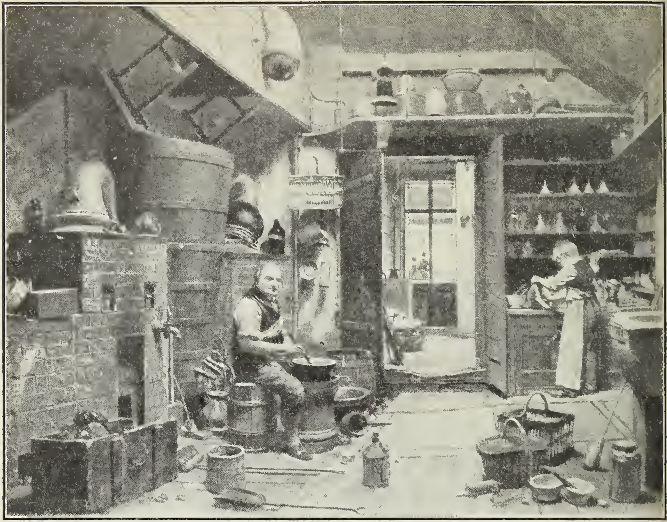
Apparatus to show the principle of an induced current of electricity.

When a coil of wire is moved across the lines of force in a magnetic field, a current of electricity is generated in the coil. Such a current is known as an *induced current.* The direction of the current changes as the coil rotates in the field, causing an *alternating* current. The principle of the induced current is used in many of our modern electrical devices.

The Electric Generator. The principle on which a flow of electricity is produced by a *generator,* which is also often called a *dynamo,* is the same as that of the induced current described above. A generator has an electromagnet by means of which a powerful magnetic field may be produced. The armature consists of many coils of wire rotated between the poles of the generator. The two ends of each coil of wire terminate in the commutator, which consists either of a pair of metal rings or of segments separated by insulating material. As the commutator revolves, it touches fixed strips of conducting material known as the brushes. These brushes pick up the electricity and allow it to be carried off by wires. Some generators have a revolving magnetic field and a fixed armature, but the principle is the same. Whenever there is *relative motion* between a magnetic field and a closed coil of wire, an electric current results. This is said to be an induced current. The strength of the induced current depends largely on the speed of the motion of the coil and the number of turns of wire in the coil, as well as on the strength of the magnet. Some of the current produced in the armature is often used to increase the strength of the magnetic field. It was Michael Faraday who made the discovery that by moving a magnet near a coil of wire a current of electricity could be produced. What a changed world ours would be if that discovery had not been made! Practically our whole electric lighting system, generators, transformers, the modern development of the X ray, our telephone, and radio are dependent upon that one idea — induction.



A modern New York City turbine generator. Does the generator make energy? If not, where does its energy come from?



Galloway

Compare this early laboratory with a modern laboratory in your school. What differences do you find? Could you perform your laboratory work with the crude tools early scientists worked with?

Alternating and Direct Current. As one side of the coil of wire in the armature passes the north pole of the magnet, a current results in a certain direction. As it passes the south pole, the current is produced in the opposite direction; thus every revolution in a coil of wire between two magnetic poles produces two currents of electricity. As the coil continues to revolve very rapidly, the current alternates, first going in one direction and then in the opposite direction. This kind of electricity is called an alternating current. The alternating current is taken off by brushes in contact with a *ring* commutator. If, however, a segmented commutator is used, the brushes take off a direct current of electricity. Either a direct current, D. C., or an alternating current, A. C., may be used with incandescent lamps. (See diagram on page 215.)

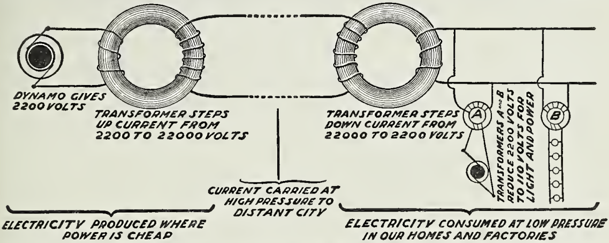
Use of Transformers. When a current of electricity is carried over a long distance, there is a very great loss of electricity due to the heating of the conducting wires. If electricity is carried over these wires at high voltage and a low current, there is little heat produced and so only a small loss of electrical energy takes place. Consequently transformers have been made which are simply devices for "stepping up" and "stepping down" the voltage of the electric current. A direct current cannot be changed by the use of the transformer into a different voltage, but the alternating current can. For this reason electric stations, especially those which are long distances from the source, usually have alternating current.

Demonstration 2. To Demonstrate the Use of a Transformer.

Materials. Two bell transformers for changing 115 volts to 6 volts, 12 volts, and 18 volts; an alternating current voltmeter reading to 130 volts; wire.

Method and Results. Measure the voltage of the alternating current electric light current.

A. Connect the transformer to the lighting circuit. Measure the voltage obtained in each of the three secondary circuits. Results?


DYNAMO GIVES 2200 VOLTS
TRANSFORMER STEPS UP CURRENT FROM 2200 TO 22000 VOLTS
TRANSFORMER STEPS DOWN CURRENT FROM 22000 TO 2200 VOLTS
A
B
TRANSFORMERS A AND B REDUCE 2200 VOLTS TO 110 VOLTS FOR LIGHT AND POWER
CURRENT CARRIED AT HIGH PRESSURE TO DISTANT CITY
ELECTRICITY PRODUCED WHERE POWER IS CHEAP
ELECTRICITY CONSUMED AT LOW PRESSURE IN OUR HOMES AND FACTORIES

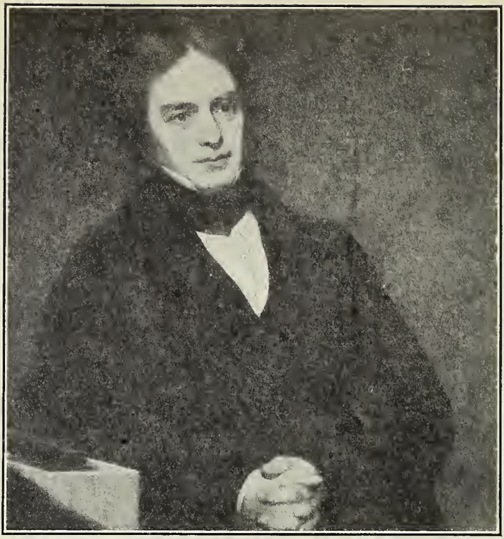
The use of transformers in a system of distribution of electrical energy.

B. Connect two binding posts of the secondary circuit of one transformer to the two corresponding binding posts of the other transformer. Connect the primary of one to the lighting circuit and what would ordinarily be the primary of the second, but which as now used is a secondary, to the voltmeter. Result? How do you account for the result?

Conclusion. Of what value is the transformer?

Application. Why are transformers used in electric lighting systems?

Principle of the Transformer. In a simple transformer there are two coils of wire carefully insulated from each other. One



MICHAEL FARADAY, 1791-1867.

MICHAEL FARADAY was born over a stable in the heart of London. As a lad he was an errand boy in a bookshop and began to read good books at the age of thirteen. He became much interested in electricity and even made experiments with simple home-made apparatus. Hearing the famous Sir Humphry Davy lecture, he tried for a position with him, and became his laboratory assistant. Much later when Sir Humphry was asked what was his greatest discovery, he replied, "Michael Faraday." . . . And so it was, for the pupil later outstripped his master and became one of England's greatest scientists, honored by the whole world. Although he made many discoveries in the field of chemistry, he is best known for his work in electricity. He discovered the principle of electro-magnetic induction, which is the basis of the making of electric power by means of dynamos or generators. This principle applied today is at the basis of all of our electric transportation, our telephone, and many other useful applications of electricity. Faraday is also responsible for the theory of electrical waves through the ether on which the discovery of wireless telegraphy is based. He married very happily, and during his later life was honored by many nations. He died on August 25, 1867.

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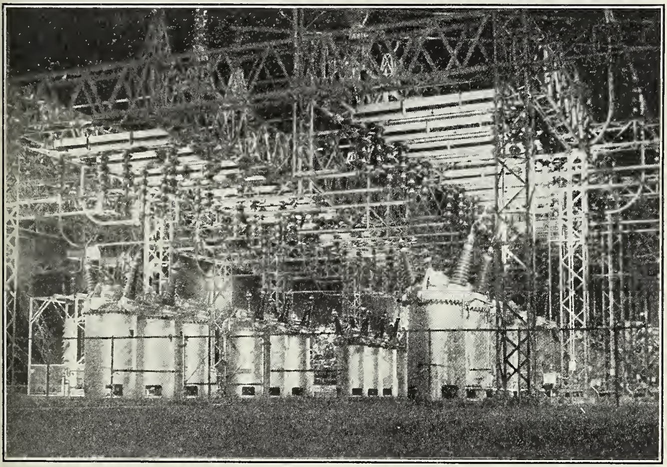
coil, called the *primary*, receives a current from an A. C. generator. Each impulse of current builds up a magnetic field which induces a current in the other coil, called the *secondary*. Since these impulses of current follow in rapid succession, there will be a series of currents in the secondary with no appreciable time between them. The change in voltage is determined by the ratio of turns of wire in the two coils. Suppose we have 120 volts in the main circuit and we wish only 60 volts, then the secondary coil will have only half as many turns of wire in it as are in the primary coil. If the primary had 4000 turns of wire and the secondary 400 turns, then the number of volts from the secondary would be 12. The number of volts in the two circuits varies directly as the number of turns of wire in the two coils. On the other hand, we should know that the strength of the current varies inversely as the number of turns of wire. That is, if we reduce the voltage to one fourth the original, the amperes will be four times the original. This means that except for a very small loss, the electrical power going into the transformer equals that coming out. A small step-down



Charles Phelps Cushing

A modern transformer station at the Wilson Dam. What is the use of a transformer?

transformer is used for operating electric toys and trains and for giving current for doorbells.

The Induction Coil. An induction coil is a device generally used to increase the voltage of a direct current by induction. There are two coils of wire: (1) the one through which the current is sent and which is called the primary coil and (2) the coil in which the current is induced, the secondary coil. The primary coil is wound around a soft iron core. When the current in the primary coil is varied or interrupted, a current is induced in the secondary coil. This is due to the fact that in breaking the current in the primary coil we alternately make and break or remove the magnetic field around the secondary coil. The device which will do this is a *vibrator* or interrupter, which works on exactly the same principle as the make-and-break vibrator on the electric bell.

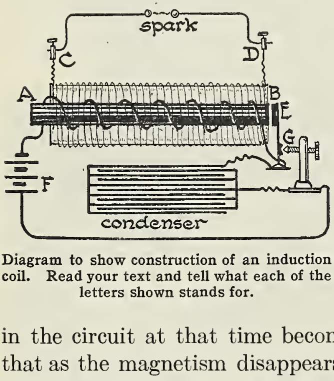
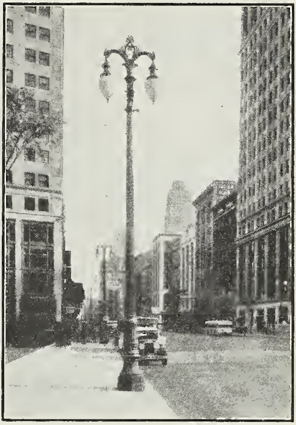


Diagram to show construction of an induction coil. Read your text and tell what each of the letters shown stands for.

In the diagram the primary circuit is the heavy insulated wire wound around the iron core. As the current passes across the point *G*, the soft iron *E* is drawn by the electromagnet toward *B*, making a gap in the circuit at *G*. A condenser in the circuit at that time becomes charged from the battery, so that as the magnetism disappears and *E* comes back to close the circuit another surge of electricity from both battery and condenser passes through the primary coil. This vibrating action is repeated many times a second. Outside of the primary coil and carefully insulated from it is the secondary coil consisting of thousands of turns of wire. If the ratio of turns is primary 10 turns to secondary 100,000 turns, then the number of volts in the secondary circuit will be 10,000 times the volts in the primary circuit, but the amperes will be only $\frac{1}{10000}$ of that in the primary. This is the type of coil used in the toy shocking machine. Moderate-sized coils are used to make sparks in spark plugs, and large coils are used in producing the X rays.

Uses of Electricity. It is estimated that in 1934 in the United States about 90,000,000 people lived in homes wired for electricity. Think of the uses of the electric current: for heat, light, and power. Think of its uses in the telegraph, telephone, and radio and of its value in lighting our homes, factories, stores, public buildings, and streets. How many other uses can you add to this list?

Street Lighting. A few years ago the arc lamp, in which an electric circuit is closed by bringing together two carbon pencils, was a common source of street lighting. Today it is rarely seen, its place having been taken by incandescent-bulb lamps. When an electric circuit is closed by the contact of two carbon pencils, great heat is generated by the resistance at the point of contact. Carbon at the point of contact becomes vaporized, and if the carbons are drawn a short distance apart, this vaporized carbon continues to carry the current of electricity. Inasmuch as this stream of highly heated vapor usually bends out in the form of an arc, this is called an *arc light.* Closed arc lights are almost always used nowadays because they last longer. This is because there is little oxygen present in the bulbs to burn them up.



General Electric Co.

A modern street fixture on Woodward Ave., Detroit, Mich. It is ornamental as well as practical.

The most important use of the heat derived from an electrical current is in the heating of the filaments of incandescent lamps to produce light. The larger tungsten lamps run from one hundred to five hundred or more candle power, and are in common use for street lighting.

Lamp Circuits. — When arc lights are used, the lamps are connected in series, each lamp taking about fifty volts. A circuit with one hundred lamps would, therefore, require 5000 volts. Incandescent lamps, on the other hand, are connected in parallel.

A 110-volt circuit would be sufficient for any number of lamps so joined.

How Electricity Is Sent to the Consumer. A few years ago it was a common sight to see the streets of cities disfigured by huge poles bearing many wires. In modern communities all telephone and electric light wires are placed in conduits underground. This use of underground cables instead of overhead wires is a great advantage as there is no trouble from broken wires in storms, less danger to people, and the streets are more beautiful. While the first installation is expensive, the wires are so well protected that they last a long time, and the final cost of underground cables is not much greater than that of the overhead system of wiring.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange these in proper numerical order. The same word may be used more than once.

chemical
magnets
rotation
segmented
mechanical
closed
parallel
cuts
steam
wire
produced
coil
indirect
electrons
generators
current
magnetic
power
alternate
rotating
water
alternating
field
commutator
manufacture
direct
electric
series

Commercial electricity is derived chiefly from (1)____ energy. (2)____ turbines and (3)____ turbines make this change in energy most economically. The principle of induction is that whenever a (4)____ (5)____ of wire is moved so that it (6)____ lines of (7)____ force a (8)____ of electricity will be (9)____ in the (10)____. This principle is used in (11)____. A (12)____ of wire (13)____ between a north and south (14)____ pole receives an (15)____ current. By using a segmented (16)____, a (17)____ current is produced. Transformers are used only with (18)____ currents. Arc lights are not much use for street lighting but if used the lamps are placed in (19)____. Incandescent lights are most used and they are connected in (20)____.

PROBLEM TEST

Electric current is generated by falling water at 2200 volts, carried over transmission lines at 154,000 volts, and used in factories at

220 volts and in homes at 110 volts. *Which of the following statements relate to things essential to make this possible?*

1. Falling water generates electricity by friction just as lightning is made.
2. Mechanical energy can be transformed into electricity.
3. Water makes steam for generating electricity.
4. A changing magnetic field induces an electric current in a coil of wire.
5. Wires carrying electric power must be well insulated from the ground.
6. Step-up transformers are required to raise the voltage.
7. Step-down transformers are required to lower the voltage and increase the current.
8. Segmented commutators are used for direct current.
9. Magnetic lines of force in the field outside the magnet go from a north pole into a south pole.
10. A galvanometer shows when a current of electricity is passing through it.

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REVIEW SUMMARY

Make out your review outline with great care. Use the following principles and generalizations unless you prefer to make the complete outline after a plan of your own.

1. Much is now known about the ultimate nature of electricity.
2. Neutral bodies become charged electrically upon gaining electrons or upon losing electrons.
3. Current electricity may be produced by chemical action.
4. Electrical energy can be measured.
5. Most of the electricity used is produced by the relative motion between a closed circuit and lines of magnetic force.
6. The characteristics of an electric current may be changed by a device called a transformer.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade equals right answers* × $3\frac{1}{3}$.

I. **A neutral piece of glass may become positively charged when:** (1) rubbed with silk; (2) it takes protons from another body; (3) it is touched by a positively charged body; (4) electrons go out of it; (5) it touches a negatively charged body.

II. **A chemical cell for producing electricity:** (6) must have an electrolyte; (7) always has a strong magnetic field surrounding it; (8) always has carbon for one of its plates; (9) has two poles called positive and negative; (10) draws electrons from one plate in the cell and heaps them up on the other.

III. **Of the various units of electrical measurement:** (11) the volt is the unit of electrical pressure; (12) ampere was the name of a French scientist; (13) current is measured in amperes; (14) the watt measures electrical power; (15) the kilogram is a measure of electrical resistance.

IV. **When a given circuit having four dry cells in series is changed so as to have two cells in series and two cells in parallel:** (16) the voltage is increased; (17) the life of the battery is decreased; (18) the amount of current delivered is reduced; (19) the watts delivered will be the same; (20) there will be three volts in the circuit.

V. **In the electric generator you may find:** (21) an armature; (22) segmented commutator for A. C.; (23) brushes for cleaning the commutator; (24) an interrupter; (25) a powerful magnetic field.

VI. **A transformer:** (26) has at least two coils of wire insulated from each other; (27) changes alternate current to direct current; (28) changes direct current to alternate current; (29) may raise or lower the voltage; (30) may increase or decrease the number of amperes, depending upon the windings of primary and secondary coils.

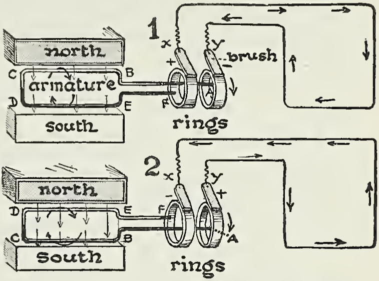
PRACTICAL PROBLEMS

1. Show that you have a thorough understanding of electrical units by determining the amount of current flowing and the cost of using an electric iron four hours, when the iron is rated as a 550-watt iron. Assume that the electricity comes to you at 110 volts and the charge for it is 10 cents a kilowatt hour.

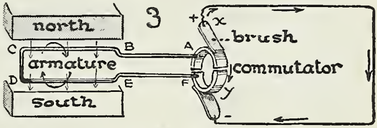
2. Devise a water analogy to explain how plus and minus charges neutralize each other. (Suggestions. A tank below ground level, which is considered zero, may be used to represent a minus charge.)

3. Make a diagram to show how six dry cells would be connected to be two in series by three in parallel.

4. Take the reading of your electric meter weekly. Calculate the weekly cost of the electricity used.



alternating current



direct current

5. Study the diagram before you attempt to answer the following question. How could you tell whether a generator you were examining would give D. C. or A. C.?

6. If the voltages in two circuits of a transformer vary directly as the number of turns of wire about the iron core, what is the number of turns of wire in the bell or secondary circuit of a transformer which has 1000 turns in the other or primary circuit? (Assume the current is supplied to the primary circuit at 120 volts and the bell receives six volts.)

7. Develop a water analogy to explain an electric circuit. Consider the level surface of the earth zero or neutral; water in a tank 10 feet deep as positive electricity, and an empty tank of the same dimensions as the other, but located below ground with its top level with the earth's surface, as negative electricity. A pipe leads from the bottom of the upper tank into the lower one. A pump is installed whose intake is at the bottom of the lower tank and whose outlet is into the top of the upper tank.

Make a good diagram. Explain how you can use this as an analogy to explain the generation and flow of an electric current in any circuit. What could you add to represent a switch or button?

LIBRARY RESEARCH READING

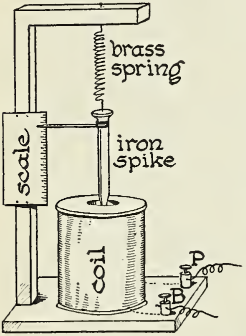
1. Life and work of Galvani.
2. Life and work of Volta.
3. Life and work of Ampère.
4. Life and work of Faraday.
5. What is an induction motor?

6. Proper care of the lead-plate storage battery.
7. The Edison storage battery.
8. Large hydroelectric developments of the world.
9. The story of "From the coal pile to the electric light."
10. "White coal" and electric energy.
11. The work electricity can do.

SCIENCE FOR LEISURE TIME

1. **A voltaic pile.** Devise a way of making a small voltaic pile. Can you think of any way to see if it will produce a current?

2. **A simple ammeter.** Prepare a coil of wire around a hollow core. Use about $\frac{1}{4}$ pound #18 wire. Connect ends of wire to binding posts *B*, *P*, to which the battery to be tested will be attracted. A nail held up by a small spring will be sucked into the coil when current is supplied. The scale will have to be made by checking against a standard ammeter before it can be of use.



3. **Make a scrapbook about electricity.** Pictures and clippings about things that (1) produce electricity, (2) use electricity.

4. **An automatic electric fire alarm.** You need for this an electric bell, dry cell, insulated bell wire, two strips of tin (cut from a tin can), and a block of wood. Place bell and dry cell in any convenient place. The block and strips of tin are to be used to make a button or switch. One end of each metal strip is joined to the wires which connect bell and battery. They are fastened to the block of wood so that their free ends overlap. They are bent so that the spring in them makes them press together tightly, closing the circuit. Place the block above the place where a fire is most likely to occur. Let a drop of melted candle wax fall upon a cold smooth metal or stone. Place this thin flattened piece of wax between the ends of the tin strips to keep the circuit open. If there is a fire the heat will melt the wax and the tin strips will come together and close the circuit. The ringing bell then sounds the alarm.

SCIENCE CLUB ACTIVITIES

1. **Excursion to electric light plant.** Find out what energy is used. Kinds of generators used. See parts on generator not in use. How energy is transferred to generators.

Instruments and their use. Day and night service; summer and winter service. Are transformers used? Changes in voltage. District where electricity is sent.

2. **Electric shocking machine.** Use a toy induction coil that someone can bring. Devise ways of connecting a doorknob so that one who opens the door will feel a shock or that he will receive a shock when he shakes hands with you. Use dry cells or a bell-ringing transformer on the house circuit to run the induction coil.

3. **Charging storage batteries.** Visit a battery-charging station. Have someone there explain the process to you.

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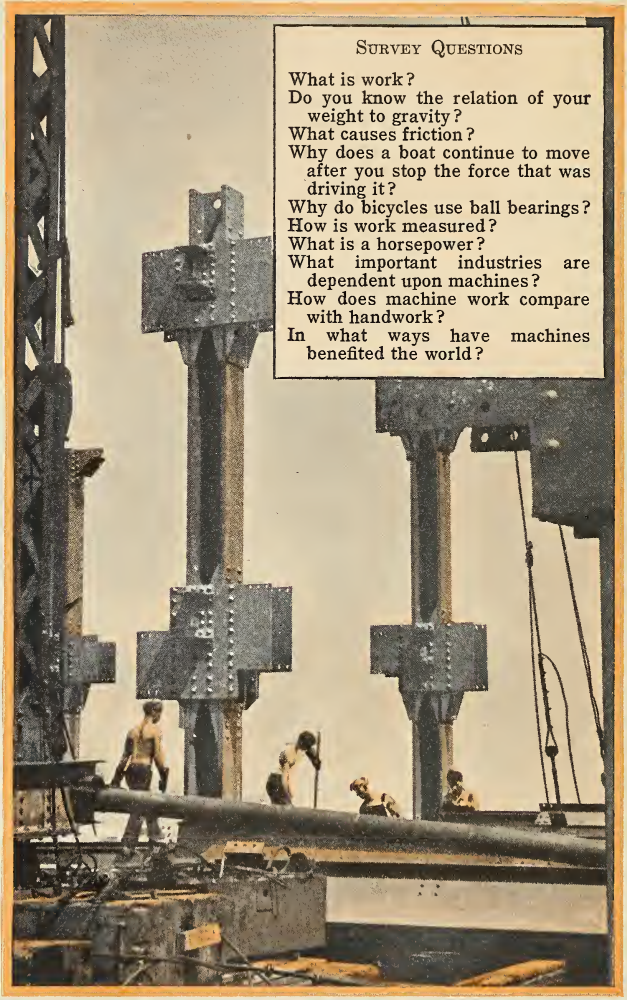


SURVEY QUESTIONS

What is work?
Do you know the relation of your weight to gravity?
What causes friction?
Why does a boat continue to move after you stop the force that was driving it?
Why do bicycles use ball bearings?
How is work measured?
What is a horsepower?
What important industries are dependent upon machines?
How does machine work compare with handwork?
In what ways have machines benefited the world?

Galloway

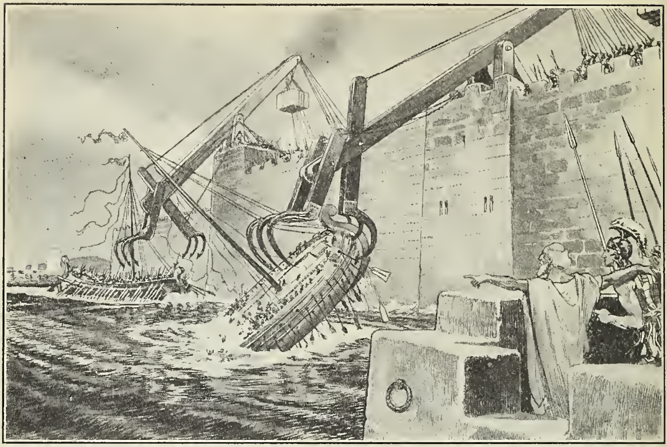
UNIT VIII

OUR MACHINE AGE

PREVIEW

The story of how man has come into his heritage of modern machines and the devices that we find in our homes today is a long and interesting one. Primitive men chipped hard stones to make axes, knives, and scrapers to remove the hair from the animal hides which they made into clothes. Some of them even had stone fish-hooks, awls, and needles. The primitive peoples of the East who first cultivated land used a crooked stick for a plow, but we know that as ancient a civilization as that of the Egyptians made use of the inclined plane, the lever, the balance, the siphon, the bellows, and the blowpipe. They knew how to use flax and spin it into linen. Weaving of cloth is a very ancient art, for we know that hand looms and other similar devices existed in very early times. But the first great inventor whom we really know much about was Archimedes. He lived over 2000 years ago in the city of Syracuse on the island of Sicily. The story of Archimedes and the golden crown is one that you already know about, but perhaps it is not so well known that he saved his city from the Roman legions by inventing devices for warfare. Livy, the Roman historian, tells the story in the following way:

"The vigorous attempts made by Marcellus to carry Syracuse by storm had certainly sooner succeeded, but for the interposition of one man, Archimedes, famous for his skill in astronomy, but still more so for his surprising invention of warlike machines. By these, in an instant, he destroyed what had cost his enemy vast labor to construct. Against the Roman vessels, which came up close to the city, he contrived a kind of crane, projected above the battlements, with an iron grapple attached to a strong chain. This was let down on the prow of a ship, and, by means of the weight of a heavy counterpoise of lead, it raised up the prow, and



The artist's conception of how Archimedes helped repulse the Romans at the siege of Syracuse. Read your text and then tell how these engines of war worked. What kinds of machines are used here?

set the vessel upright on her end." It is also said that he used concave mirrors to set fire to the Roman ships that were close to the walls of the city.

In this age of speed we are constantly looking for new machines, new sources of power, and new accomplishments in the way of greater control of natural forces. In countries where labor is cheap and mechanical equipment is small, it is often said that the introduction of machinery is unnecessary. In China you can hire a man to work for you a whole year for about $50. However, if we reckon all the electricity used in the United States, in its equivalent of mechanical energy, it is cheaper than the cheap help of China; for on the average the power of one man for a year costs only $7 in the equivalent of electrical energy. It is estimated that in 1930 there were 6.7 horsepower available for every farm worker in the United States and that in Montana, the state having the highest horsepower available, there were 22.5 horsepower for each agricultural worker. This means that farmers today are well-equipped with tractors, reapers, threshers, binders, and other useful farm machinery It will be the purpose of this unit to show

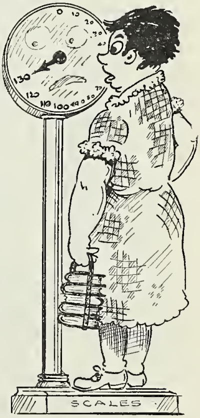
how machines lighten the labor of the world in home and factory, and to help you understand the principles which underlie their operation.

In this unit we shall review a number of topics covered in the work of last year, but at the same time additional material will be given so that even if you are one who remembers last year's work very well, you will still learn a good many new facts and how to apply them. Before beginning the study of this unit, recall what you have already learned. The following are some of the principles and generalizations that have already been reached. Can you add any to this list?

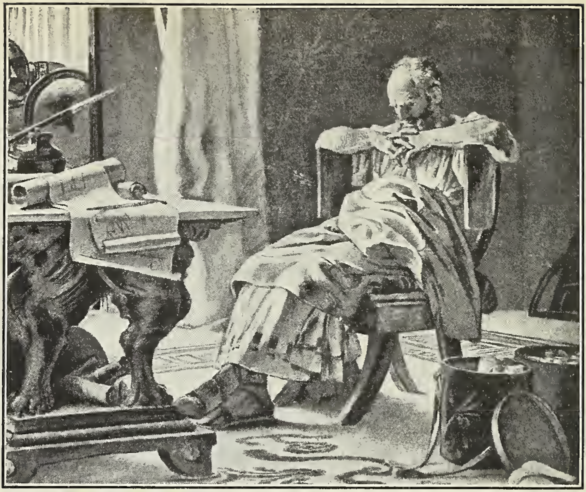
1. Gravity, friction, and inertia resist a force acting to set matter into motion.
2. Work is done when a body is set into motion or a moving body is stopped.
3. With machines a small effort can overcome a large resistance or slow motion can produce rapid motion.

PROBLEM I. WHAT ARE THE FACTORS INVOLVED IN WORK?

What Is Work? As defined in science, work is the overcoming of resistance through space. We may lift a pail of water from the floor to the table. That is work. If we merely hold the pail of water still, that is not work. Again we may draw a heavy trunk across the floor. That is work. If we push against the wall with as much force as we did in moving the trunk, but do not move it, that is not work. To do work, then, there must be some *accomplishment*. Unless we move the object our effort is in vain and no work is done. In the cases just cited, our effort is directed against two types of resistance. We overcome friction when we drag the trunk over the floor, and we overcome gravity when we lift the pail of water. A body is lifted by overcoming the resistance of gravity, which is defined as the pull of the earth on objects. Since gravity in any given



Read your text carefully and then try to explain this picture.



ARCHIMEDES, 287–212 B.C.

YOU all know the story of how the Greek mathematician, Archimedes, was asked by the ruler of his native city to find out if a new crown he had just had made was of pure gold. The philosopher was greatly puzzled. One day while bathing, he realized that the amount of water displaced was equal to the volume of the part of his body that was submerged. He is said to have rushed from his bath into the street, crying, "Eureka! Eureka!" which means "I have found it." How was he able, from this discovery, to prove that the crown was not pure gold?

Archimedes was also a famous mathematician and wrote books on this subject. He was the first person to recognize the use of the lever, and invented the compound pulley and the spiral screw for raising water. Our present-day auger is another example of Archimedes' genius.

When Syracuse was besieged by the Romans, Archimedes invented new types of war engines for its defense, and suggested that burning glasses could be used to set fire to the enemies' ships. The people of Syracuse were thus able to hold out against the Romans for three years with the aid of these devices. When the city finally fell, Archimedes was slain in the massacre.

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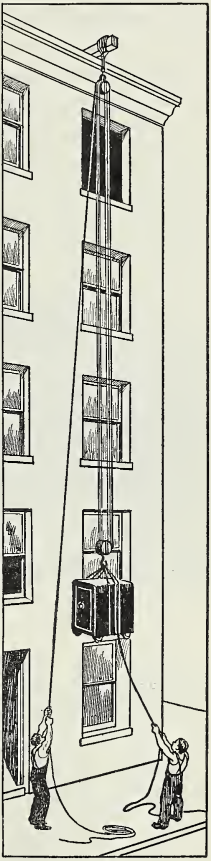
place on the earth is an unvarying force, other forces are measured in the same units. Hence we have the terms *pound-force* and *gram-force.* We must use a force of 10 pounds to lift a stone which weighs 10 pounds.

How Work Is Measured. The amount of work you do depends upon the force which you use and the distance that you move an object. For example, if you lift 10 pounds of any material 3 feet, you do more work than when you lift 10 pounds 1 foot. Work, then, is equivalent to force times distance. The English unit of work is the *foot pound.* One foot pound is the work accomplished when a force overcomes a resistance of one pound through a space of one foot. If you lift 10 pounds of flour one foot high, you do 10 foot pounds of work. If you lift 10 pounds 5 feet, you do 50 foot pounds of work. If 10 pounds of matter fall 5 feet, gravity has done 50 foot pounds of work upon it. In the metric system of measurement, when one gram is lifted one centimeter, one gram-centimeter of work is done.

Gravity and Friction. When we move a body horizontally, we are not dealing with gravity. If the body is at rest, we must apply force to overcome the resistance caused by inertia and friction. But after it is once in motion, it requires force only to overcome the resistance of friction, in order to keep moving at a uniform speed.



Explain this diagram. How is the mechanical advantage obtained? How could you make it greater than it now is?

Mechanical Advantage. We use a machine ordinarily to overcome a force greater than that which we apply. If by means of a machine we can lift 400 pounds by applying a force of 50 pounds, then the mechanical advantage of the machine is 8;

it is equal to the weight lifted divided by the effort applied. This is represented by the formula:

$$\text{Mechanical advantage} = \frac{\text{Resistance}}{\text{Effort}}$$

This statement of the law of machines can be applied to every type of machine. We must remember, however, that in this equation we have neglected to consider friction. In actual use of the machine we would have to do an additional amount of work to overcome friction, as we saw last year.

A large harvester pulled by a tractor. This is a more efficient means of pulling a harvester, especially in a hilly region.

Efficiency of Machines. In practice we are unable to get as much useful work out of a machine as we put into it. Friction cannot be eliminated entirely, and a certain amount of energy must be expended in overcoming it.

The ratio of useful work done by a machine to the work done upon it is known as the efficiency of the machine.

$$\text{Efficiency} = \frac{\text{Useful work done by machine}}{\text{Work done upon machine}}$$

If the work accomplished by the use of a machine is but three fourths of the work actually done, its efficiency is 75 per cent.

No machine is 100 per cent efficient. In every machine some work is done in overcoming friction, so that the total work done is more when the machine is used than it would have been could the work have been done without the machine. Friction between moving parts of machines is often reduced by use of oil which fills in the low spaces in the surfaces.

Suppose you wish to raise a pail of mortar weighing 40 pounds from the ground to the top floor of a building 30 feet above. You can lift the pail 3 feet high and do $40 \times 3 = 130$ foot pounds of work. If you could reach 30 feet high, you might raise it the whole distance and do 40×30 or 1200 foot pounds of work. But you cannot reach 30 feet high. If you carry the mortar up, you carry your own weight of say 100 pounds up the 30 feet. This adds 100×30 or 3000 foot pounds more. To carry the mortar up, you would have to do 4200 foot pounds of work. If it were possible for you to use a fixed pulley, you could pull down on a rope with perhaps a 45-pound force. So with the machine you do 45×30 or 1350 foot pounds of work. Nevertheless, you can see that even though the total work (1350 foot pounds) is greater than the useful work (1200 foot pounds), yet the use of the machine is an advantage. Can you explain how?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

gravity
weight
motion
acts

force
depressions
move
work

stop
resistance
pounds
reduces

12
rubbing
overcome
32

advantage
efficiency
metal
2

The three types of (1)____ to force are: friction, inertia, and (2)____. Mechanical (3)____ is the ratio of (4)____ to effort. The work required to lift 8 pounds through a distance of 4 feet is (5)____ foot (6)____. One must use (7)____ and do (8)____ in order to (9)____ friction. Oils fill the (10)____ in (11)____ surfaces and (12)____ friction. A body at rest cannot (13)____ nor a moving body (14)____ unless some outside force (15)____ upon it and then (16)____ is done.

PROBLEM TEST

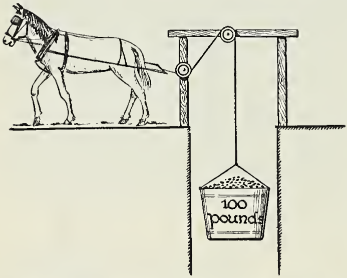
In the fall, after the swimming season is over, you are given the problem of getting a heavy float (one ton) out of the water and moving it far up onto the beach where high tide cannot reach it. You have at your disposal graphite, lubricating oil, strong rope, timbers, cylindrical iron bars, a wheelbarrow, shovel, crowbar, jackscrew, and in addition any one simple machine you may select. Two other boys will help you.

1. What are the resistances you must overcome?
2. Give details about your proposed method of overcoming them.

PROBLEM II. WHAT IS POWER?

Power. When we use the term *power*, we may mean: (1) a source of mechanical energy, as water power; (2) the force applied to a machine, as effort applied to one end of a lever; or (3) the rate at which mechanical work is performed, as an engine of ten horsepower. It is only the last meaning which we need to explain.

What Is Horsepower? The term *horsepower* came into use in England before the time of steam. Watt found, by test, that the average draft horse in walking 220 feet per minute could continuously lift a 100-pound weight. The work done amounted to 22,000 foot pounds per minute. Watt, desiring to give full measure in the engines he was manufacturing, added 50 per cent to this and made 33,000 foot pounds per minute the standard for his engines. This remains the standard horsepower everywhere today. A horse would need to walk at the rate of 330 feet per minute while lifting a weight of 100 pounds to perform our standard horsepower.



The average horse is able to lift 100 lbs. of coal at the rate of three and two-thirds feet per second. How much can be lifted at the same rate by an engine of standard horse power?

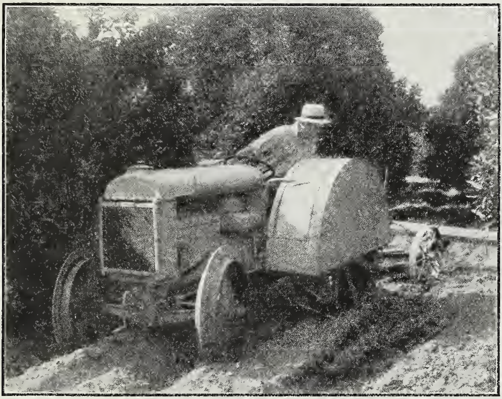
If an automobile engine develops 20 horsepower, then 33,000 × 20 gives 660,000 foot pounds of work per minute.

How We Calculate Horsepower. In order to calculate horsepower it is necessary to divide the amount of work accomplished per minute by 33,000. Substitution in the formula simplifies this calculation.

$$\text{Horsepower} = \frac{\text{Pounds (resistance)} \times \text{Feet (distance)}}{\text{Minutes} \times 33{,}000}$$

You can calculate your own horsepower by timing yourself running up several flights of stairs in a tall building.

How much horsepower would you use in climbing Washington Monument? Obviously it depends upon your weight and the speed at which you climb. If you weigh 150 pounds and make the climb of 550 feet in 25 minutes, you can find your horsepower by using the formula above.



Wright Pierce

A small tractor in a citrus grove. How does it accomplish work?

$$\text{Horsepower} = \frac{150 \times 550}{25 \times 33{,}000} = \frac{1}{10}\ \text{Horsepower}$$

The Importance of Power in the World. Everywhere today we see evidences of the use of power. Water power has been harnessed so that in this country it is estimated that we have today harnessed nearly 15,000,000 horsepower from our streams and rivers, but we use only a small portion of the available horsepower from these sources. Steam has been estimated to give us over 200,000,000 horsepower of energy each day in areas where we cannot use water power. Of course much of our water and steam power is transformed into electrical power used in both lighting and work. Power in such amounts has revolutionized industry, for it means much more work done with the use of machines than in the old days of man power. This is the age of power and the machine. It means more work done by the stored energy of fuels and water through the use of machines and less done by man. It means shorter hours of labor and more time for leisure.

George A. Douglas

Traffic on 5th Ave., New York City. What kind of traffic is restricted to this avenue? Why?

Horsepower in Transportation. It is evident to anyone who travels a public highway that the horse is no longer a common source of power for transportation. Agriculture has been about the slowest to give up the horse for the new motor power. The number of horses on American farms declined from 21,000,000 in 1918 to 12,000,000 in 1933, a decrease of about 44 per cent. The use of tractors increased in the same period from 80,000 in 1918 to 1,000,000 in 1933, an increase of 1250 per cent. In 1918 the production of automobiles and motor trucks was 1,100,000. In 1929 it was 5,600,000, but in 1933 the production for the United States and Canada had decreased from this high to a little over 2,000,000, due to the effects of the great depression. The number of cars used in the United States in 1933 was over 24,000,000. Suppose these range from 35 to 90 horsepower. You can readily see that the total horsepower used in automobile transportation is a staggering figure.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

multiply
using
less
saving
horse
hour
stored
engine
actual
fuels
power
animals
more
divide
steam
man
standard
average
minute
oil

One (1)____ horsepower represents (2)____ work than the (3)____ horse can do. To calculate horsepower (4)____ work accomplished per (5)____ by 33,000. Energy (6)____ in water and in (7)____ is being used more and more thus (8)____ the energy of man. The gasoline (9)____ has largely replaced the (10)____ on our highways.

PROBLEM TEST

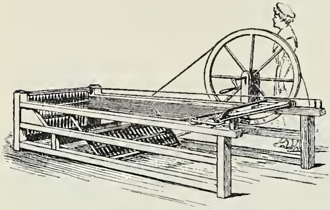
Some of the following questions require you to do some numerical calculations. List your answers in numerical order.

1. Watt found that the work an average draft horse could do in one minute was ____.
2. An engine of 10 horsepower in one minute can do ____.
3. The horsepower of an automobile that does 1,320,000 foot pounds of work per minute is ____.
4. The work required to lift 50 pounds 20 feet in one minute is ____.
5. When one ton (2000 pounds) of water falls 25 feet, the work it is capable of doing is ____.
6. When 200 cubic feet of water (density 62.4 lbs. cu. ft.) flow through a penstock per minute and turn a turbine 20 feet below the water surface, the power it can deliver to the wheel is ____.
7. When water in a tank is 10 feet deep, the pressure it exerts on a square foot of the base of the tank is ____.
8. Water that is 10 feet deep in a mill pond exerts a pressure on any surface at that depth of ____.
9. If you hold a 10-pound weight perfectly still in your hand for 15 minutes, the amount of work you do is ____.

PROBLEM III. WHAT CHANGES IN INDUSTRY HAVE BEEN BROUGHT ABOUT BY MACHINES?

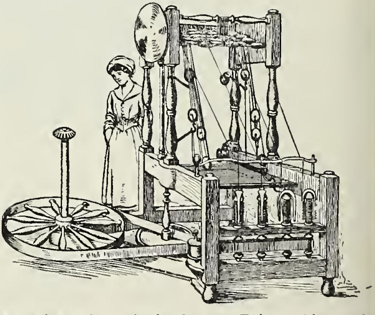
Great changes have taken place in all kinds of work within the last 100 years. The pages that follow will tell a little about some of the more important changes that have been brought about through the use of modern machinery.

The Spinning Jenny. Weaving was among the earliest household arts. The hand loom was used long before the time of Christ, and the Middle Ages saw some of the most beautiful products of this machine. Between 1767 and 1769 two Englishmen, named Hargreaves and Arkwright, invented the spinning jenny and the spinning frame. These inventions took the place of the spinning wheel in making thread. Cotton was spun by passing it between two pairs of rollers, one moving slowly and one rapidly, one roller of each pair being covered with leather. As cotton passed between them, it was twisted into a fine thread. This invention, together with that of Eli Whitney's cotton gin, gave the impetus that made the great cotton-weaving industry of today what it is.



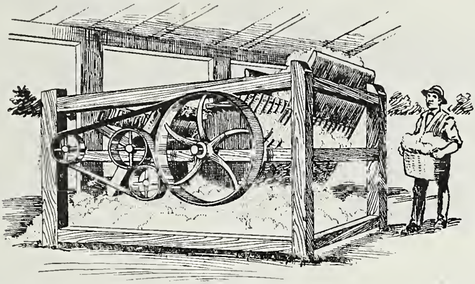
Hargreaves' spinning jenny. It was named after his wife. One person could spin from twenty to one hundred times as much yarn with this as with a spinning wheel.

The Cotton Gin. Eli Whitney, a young northern inventor, happened to have a position as teacher in the home of one of the prominent southern families shortly after the war of the revolution. While there he became interested in the problem of separating the cotton seeds from the cotton fiber. This work in the past had been done by slaves, who picked the seeds out by hand, so that very little cotton was produced. This young inventor made a machine in which the raw cotton was fed into a hopper, and passed between cylinders, one containing small circular saws and the other furnished with brushes, which, after the seeds were pulled out, swept the cotton clear of the machine. This early gin was run by two horses or two oxen and could clean 5000 pounds



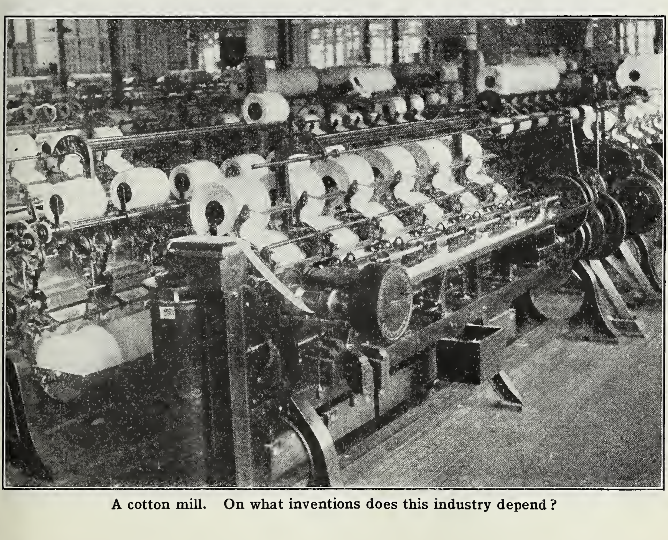
Arkwright's first spinning frame. This machine made a harder and stronger thread than the "jenny" and spun flax, cotton, or wool.

of cotton bolls a day, giving an output of about 1000 pounds of cotton. This machine was patented in 1793, the year Arkwright died. As a result of this machine the export of southern cotton went up from about 11,000 bales in 1793 to 4,000,000 bales in 1860.

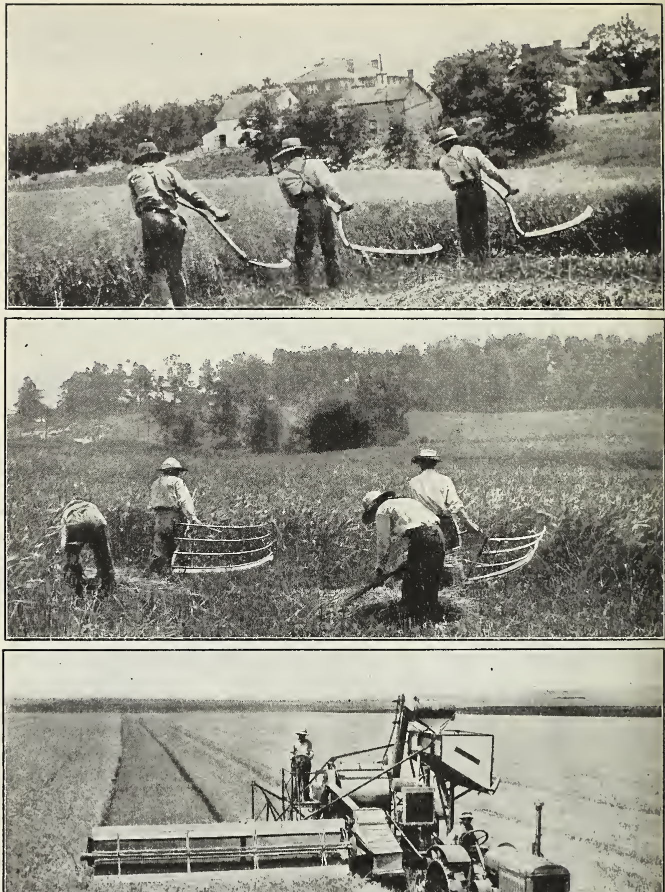


An early cotton gin. The essential parts of the machine were rollers covered with small teeth, which took out the seeds, and revolving brushes, which separated the picked cotton from the seeds. Can you find these parts in the picture?

The Result of These Inventions. These two inventions made possible the great industry of cotton-cloth weaving. The automatic



A cotton mill. On what inventions does this industry depend?



International Harvester Co.

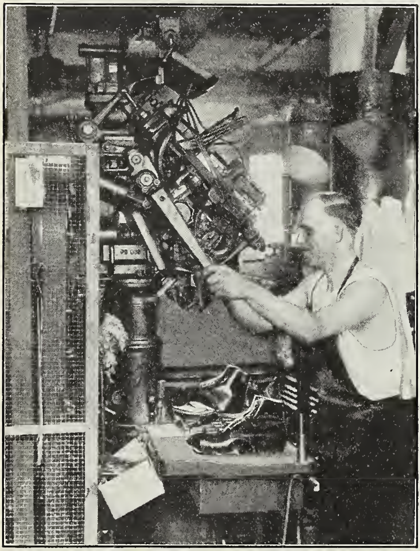
With a scythe, a man could cut about 3 acres of grass; but the cradle, which was a little more efficient, was used for cutting wheat. A modern combination of tractor, harvester, and thresher, shown below, cuts from 40 to 50 acres a day and delivers the grain, after cleaning, into a tank.

machinery of today first turns the cotton into thread or yarn, then weaves it into cloth, and finally prints it with colors. A pound of cotton makes almost 95 miles of cotton yarn, but thread as fine as 1000 miles to the pound has been made. The modern factory is filled with automatic pickers, carders, drawing frames, which take the cotton and pull it into an even thickness of cotton batting. Then it is drawn through great machines called mules, where it is twisted into thread and finally spun or woven into cloth. There are many variations in this process, and many different kinds of looms. Perhaps you can visit a mill in your locality and report to the class on the processes as you saw them.

The Reaper in Agriculture. Agriculture always has been and will be a great industry. People must eat, and food comes from crops. Great cereal crops are necessary for the life of a nation. As people multiplied on earth, the need for food increased greatly. It is always difficult to get a roving population to help reap grain at the time of harvest. Crops were often wasted because of lack of help at the time it was needed. Cyrus McCormick was brought up in the Middle West when this problem troubled farmers. His father in 1811 had made a model of a reaper which did not work satisfactorily, so young McCormick started to improve this model, and in 1834 he had made a machine on which he took out a patent. It was a clumsy affair, but it cut grain much faster than men could do it. But the reaper was of doubtful value to the farmer because he had to have a number of men follow it and bind up the grain after it was cut. Eventually another inventor named Withington produced a binder which was incorporated with the reaper, so that the machine now did the work of a dozen men with only one man driving it.

Since the early days of the reaper and harvester, many improvements have been made, so that today great reapers, cutting a swath 30 to 40 feet wide and drawn by tractors, do the work of hundreds of men each day.

The Plow. Along with the reaper may be told the story of the plow, which was first a forked stick, then a wooden wedge, later an iron-pointed plow, until in 1855 James Oliver invented the modern iron plow. Later the coming of the gasoline engine and tractor made it possible to use 3 to 16 or more disk-shaped plows drawn by a tractor. This makes crop production on a large scale possible. When we add to the discovery of the reaper and the gang plow the binder and the various processes by which grain is milled and made into cereal foods, we can see that modern inventions have made possible the feeding of the added population of the earth.



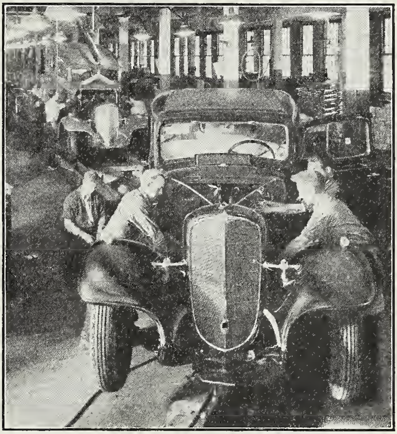
Galloway

In the modern shoe factory there are machines that make a complete shoe.

The Shoe and Leather Industry. It is a far cry from the first shoes made to those of today. Primitive man may have worn crude sandals of skin, which the Greeks and Romans later improved upon. The American Indian wore moccasins, and many of the peoples of eastern Europe still prefer this kind of foot wear. Up to the 10th century the sandal was used in England, but then came the beginning of the modern shoes, a heavy leather sock. This soft leather shoe was worn with wooden clogs out of doors to protect the feet from water and mud. In the 16th century woven stockings came into use and with them came the shoe with heels. Our first American shoes were of heavy cowhides, the leather being tanned with oak bark and the boot oiled with fish oil to make it flexible and waterproof. Shoes were made by cobblers who traveled from house to house, making shoes for the family at a single visit. With the Civil War came a demand for large numbers of shoes, so sewing machines were invented that would sew leather. This was the beginning of the shoe factories. Since that time a series of inventions have revolutionized the shoe industry, and now great machines turn out hundreds of shoes in the time it took the cobbler to make one pair. Although shoe machines are now made that turn out a complete shoe without a workman even directing the machine, most shoes pass through as many as 200 handlings and almost that many machine operations. Even though the boot-and-shoe industry is not as great in the dollar-and-cents production as some industries, being a little more than $1,000,000,000 a year, still it is very important because it gives work and money to thousands of people who raise the cattle and to those in the leather industry.

The Motor Industry. This problem would not be complete without a word about the newest and one of the greatest industries in this country. Forty years ago a few men like Henry Ford had the foresight to see that the gasoline engine was destined to revolutionize transportation and were already beginning the manufacture of a few cars. At the peak of production in 1929, 5,621,715 cars and trucks were produced in a single year, having a total value of over $3,500,000,000.

In automobile manufacture, machinery is used to an unusual degree. Not only do auto parts have to be cut or pounded, or pressed into shape by great machines, but the assembling of the many different parts is done by building up the auto as it passes from worker to worker on a long track. The auto is always moving toward a point where it will be rolled off to go out to the testing grounds under its own power. There are thousands of parts to the frame, the



Courtesy General Motors

The assembly line in a big automobile plant. How do the cars move?

motor, the body, steering gear, and wheels, and each part has to be made by machines. What a wonderful accomplishment for the machine age!

Other Industries. We might go on and tell of some of the many other industries which depend upon machines. Think of a world today without canned goods, and yet the great industry of making cans and of filling them with perishable fruits, vegetables, meats, soups, condiments, and beverages is all dependent upon machinery and the discovery of the Frenchman, Appert, who in 1810 gave to the world the simple fact that boiling and then sealing the contents of a can or jar would preserve the food inside indefinitely. Think of the great meat-packing industry which is next to the auto industry in terms of the value of its products, and of petroleum refining, an industry that goes hand in hand with the use of the motor car and scores of other industries which in 1929 had nearly 9,000,000 workers and a total output of over $70,000,000,000 for the year.

SELF-TESTING EXERCISE

Select from the following list the words which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

weaving
Ford
Oliver
motor
plow
tractor
wheat
cotton
binder
Whitney
machinery
40
spinning
leather
manual
Hargreaves
harvesting
20
threshing
McCormick
transportation
reaper
inventions
greatest

The (1)____ jenny was invented by (2)____ and the (3)____ gin by (4)____. These two (5)____ made possible the great (6)____ weaving industry. The (7)____ invented by (8)____ has made the greatest change in (9)____ grain, while the (10)____ invented by Withington increased the efficiency of the machine and reduced the amount of (11)____ labor required. Automatic (12)____ has perhaps reached its greatest height in the (13)____ industry. In (14)____ years this has become the (15)____ industry in the country.

PROBLEM TEST

You visit a cotton plantation in Georgia. There you see cotton being picked from the plants and put into a bag which is made of cotton. The question comes to you: Why are the two so different? What has given the short fibers their new capacity to act as a container? What industries are involved? What machines have been used? *Make a list of the different machine processes through which the cotton has probably passed in its transformation from loose cotton into a cotton bag.*

PROBLEM IV. WHAT THE MACHINE AGE IS DOING FOR US

Machines Lighten Labor. Egyptians built pyramids through the labor of great multitudes of men who used inclined planes by building great mounds of earth up which they dragged the huge blocks of stone as the pyramid rose higher and higher. The Greeks and Romans employed slaves for power to row their galleys, yet a small yacht of today has far more power. The farmers of olden times worked with their hands; today they use tractors and other machinery. Road building a few years ago was done entirely with hand tools, while today we have stone crushers, cement mixers, and surfacing machines.

Machines Do Fast Work. If you have ever seen a railroad being built, or a concrete roadway being laid, you probably saw the traveling crane that lays tracks about as fast as the men can nail them down, and the road-making machines that create cement roadways at the rate of hundreds of feet a day. Pipe lines are laid by means of ditch diggers and machines which automatically lay the pipes. Buildings go up with a rapidity that seems incredible when we compare it with the slow work of the carpenters and masons of a few years ago. An example is the great Empire State Building which was constructed in less than a year. Production of all sorts has been tremendously speeded up by machines.

Machines Make for Greater Production of Goods. Compare the production of shoes by hand with that of the modern machine. Think of the glass industry where until a few years ago glass was largely blown by individual workers, while today machines do the work infinitely faster and more smoothly. Think of the work done by the steam shovel compared with that of the gang of men. Take any industry you please and you will see that machines have greatly increased production.

Machines Make for Greater Accuracy. Man, no matter how careful he may be, is not as accurate as a machine. A man may become tired, he may be nervous, he may have slept badly, or he may have taken too much to drink. All of these things interfere with his accuracy. But the machine is mechanical and is built accurately so that it produces accurate goods; therefore, the goods are better and often bring higher prices.

Galloway

The Empire State Building under construction. This building, 85 stories high and towering 1045 feet above the street, was completed in less than a year. Name some machines that helped make this possible.

Machines Reduce the Cost of Production. Although labor receives more than at any time before, yet because of fewer workmen needed, the machines have reduced the cost of production. One machine can do the work of many men, and can do it more quickly and more accurately.

Machines Give a Higher Standard of Living. Many machines serve to utilize waste products, farm materials, and other things that would be wasted because of seasonal abundance; these are used now, thanks to machines. This tends to raise the general standard of living, for things which were luxuries before the machine age now have come to be within the reach of everyone, as is shown by the fact that people of the working class have many more automobiles and better living conditions than at any time when machines were not available.

Machines Have Given Us Better Ways of Transportation and Communication. No one can deny that the machine age has increased our speed of living. We get around faster, we do and see more things; we travel from place to place in motor cars, boats, railroads, and airplanes; and we communicate by telephone, telegraph, and wireless. One of the new industries which has made a tremendous difference in the life of the farmer, the explorer, and isolated people generally, is that of radio. In 1931 the Department of Commerce estimated that three billion dollars were invested in all branches of the radio industry. According to the *Radio Retailer*, in 1930 the public owned 15,000,000 radio receiving sets, in which $500,000,000 had been invested.

Do Machines Make for Unemployment? There is another side to the machine age. We hear a good deal about machines throwing people out of work. The world has been in the throes of a great depression in which millions of people were out of employment. Is it all the fault of machines? There has been a great increase in the number of machines, as shown by the record of patents taken out. In 1890 there were 208,000 patents taken out; in 1900, 221,000; in 1910, 314,000; in 1920, 384,000; and in 1930, 421,000.

Undoubtedly machines do make for unemployment in factories. In 1919 there were 9,000,000 people employed in factories, and in 1929, 8,500,000, while in the same period production increased almost 60 per cent. To make that amount of goods without new machines, 14,266,000 persons would have been employed. Instead of 5,000,000 more people at work, we actually had 500,000 less. To put it another way: during this time while the population increased and gave industry more men and women to work, there were actually less men and women able to find work in factories in spite of this increased production of goods. This same story can be told for agriculture, where tractors and gang plows are doing work better than man can do it; in mining and smelting, where machines do work that man used to do; in the building trade, where machines drive rivets and bolt steel beams together, and other machines which spray on paint instead of using men with brushes to do the work. Everywhere we see that machines are doing the work of man more rapidly and more efficiently than he can do it. Take, for example, the recent invention of the photoelectric cell which, since the discovery of the vacuum-tube amplifiers used in radio, has come to do work which people thought could only be done by

From Ford Co., Detroit

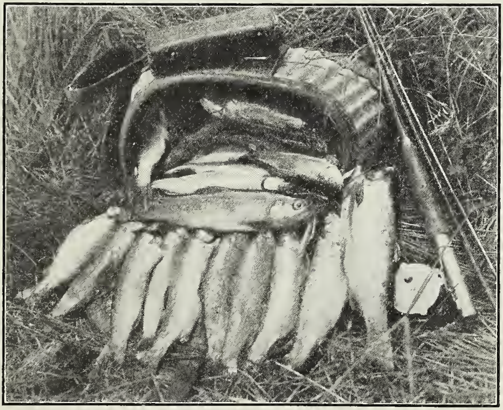
Workmen coming out from a huge automobile plant in Detroit, Mich. What other industries besides the automobile use large numbers of workmen?

man. For example, it counts money, throws out counterfeit bills, tells colors better than the human eye, directs traffic, opens doors, counts moving people and vehicles, times races, sorts fruits, eggs, and vegetables, determines the thickness of cloth, records the amount of smoke in tunnels and cities, and is indispensable in television and sound pictures. It is a mechanical eye which never knows fatigue or eyestrain, and hence is more reliable than man.

Inventions Create New Industries. While new inventions and new machines often reduce the amount of available jobs, yet a new industry may develop from the inventions and give employment to many more. If the automobile had not been developed by many inventions, there would be no automobile industry today. Not only does the automobile give employment to many thousands of workers where the automobiles are made, but to many thousands more who sell and distribute the automobiles. In addition, the automobile makes a market for oil and gasoline. It gives employment to men in filling stations, garages, repair shops, and helps out the rubber industry by requiring many tires. The automobile, because of insurance requirements, gives employment to many insurance offices and to lawyers. The automobile has also had a large influence in the building of better roads.

And so while, in a narrow view, one may condemn the machine for taking work away from man, if one takes a broad view of the whole field, it will be seen that inventions of new machines open up new industries which frequently more than compensate for the reduction of work in other fields.

What Can We Do about It? Evidently mankind, if he is to find work, must work fewer hours and double up with those who have no work. How this can best be done is not for discussion here, but one thing does come out of it which we should be interested in. If machines make shorter working hours, then we will have more time for leisure, more hours for play, and more time for self-improvement. Too many people today do not know how to use leisure time. Think of all the things your general science course has done to make your leisure time more interesting. You can now work out projects and make interesting things; you can go on a hike in the country, or make a visit to a factory and observe with understanding eyes; you now know how and where to look for interesting books and magazines which will tell you some of the



Wright Pierce

A good catch. Fishing is an excellent sport for your leisure time.

things you want to know about science; you can have hobbies such as fishing, gardening, collecting rocks and minerals or stamps. You can play games such as horseshoes, ping pong, tennis, and golf, all of which will help you to be happier, healthier, and more alert.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

increased
faster
useful
slower
higher
costly
create
employment
man
accurate
health
production
lower
standards
industry
industries
reduce
reduced
inaccurate
derived

Machines are more (1)____ in their work than (2)____. They also do their work much (3)____ than men do. For this reason they (4)____ the cost of (5)____. Among the benefits (6)____ from machines, we have higher (7)____ of living and better (8)____ for the workers. Machines have (9)____ the hand work in many (10)____ and so have (11)____ unemployment, but at the same time new inventions frequently (12)____ a new (13)____ which gives (14)____ to many people.

PROBLEM TEST

In a residential development adjoining a city, sewer pipes are to be laid six to eight feet below the surface. About three fourths of this area consists of an even grade of clayey sand, the rest is a glacial deposit of sand, gravel, stiff clay, and some boulders weighing as much as one half a ton.

What machines would you suggest be provided in order to do this job as efficiently as possible?

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, include the following important generalizations in your review outline. Do not neglect the less important details which are essential to a complete review.

1. Work is done when a resistance, as gravity, friction, or inertia, is overcome.
2. No machine is 100 per cent efficient.
3. Horsepower is the unit for measuring the rate of doing work.
4. Modern machines have produced great changes in industry.
5. Machines do more accurate work than men and they do work faster without fatigue.
6. New inventions may increase unemployment or they may create greater need of employment.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers* × $3\frac{1}{3}$.

I. **Work is done when:** (1) one pushes against a brick building with a force of 200 pounds; (2) one lifts a pail of water weighing 40 pounds from a well 10 feet deep; (3) one holds the pail of water near the top of the well and prevents it from falling back into the well; (4) a ball player catches a long fly in center field; (5) the batter hits a home run.

II. **Man makes use of friction when:** (6) sand is put on the rails in front of the drive wheels of a locomotive; (7) he oils the bearings of a bicycle; (8) he starts an automobile from rest; (9) he stops an automobile quickly; (10) he cools an engine by flowing water.

III. **When the mechanical advantage of a machine is 4:** (11) a resistance of 20 pounds requires an effort of 5 pounds; (12) the effort must move 4 times as far as the resistance; (13) 4 pounds can balance a resistance of 16 pounds; (14) if the resistance is moved 16 feet, the effort will move only 4 feet; (15) the resistance is greater than the effort but the distances through which they move are equal.

IV. **A machine for making cotton thread automatically:** (16) is the cotton gin; (17) was invented by Eli Whitney; (18) is the spinning wheel; (19) is the spinning jenny; (20) was used by the Romans nearly two thousand years ago.

V. **The development of the automobile has been a benefit to man because:** (21) it has increased employment; (22) it has reduced the demand for horses; (23) it enables him to be in the country more; (24) it has increased speed of travel; (25) riding gives him enjoyment.

VI. **Machines are of more value than harm to mankind because:** (26) they lighten labor and give more leisure time; (27) they make less work for the laborer; (28) they do more accurate work than man; (29) they create new industries; (30) they tend to create an overproduction of goods.

PRACTICAL PROBLEMS

1. Why is it impossible to build a machine which will have an efficiency of 100 per cent?
2. Why should a watch be given expert attention about once a year?
3. What is the purpose of using the "grease gun" on the automobile?
4. What is a "hot box" on a railroad car and what causes it?
5. What invention has been the cause of increased employment or decreased employment in your locality?

LIBRARY RESEARCH READING

1. Perpetual motion possibilities.
2. The life and work of Eli Whitney.
3. The story of Howe and the sewing machine.
4. The development of harvesting machinery by the McCormick family.
5. An account of some big industry: steel, flour, canning, cement, lumber, oil, textile, celluloid, paint.
6. Lubricants and lubrication.
7. When the earth's coal is gone, what?
8. Energy from winds, tides, rivers, sun.
9. History and future of Niagara Falls.
10. American inventors.

SCIENCE FOR LEISURE TIME

1. **Work of walking to school.** The work you do in walking is really done in lifting your body. To find how high you lift your body at each step, hold a piece of crayon touching the blackboard when you stand side to it. Walk along at your natural gait, keeping the arm rigid with the body. The crayon makes a rising and falling curved line. Find the number of inches from the average of the lows to the average of the highs. This is the distance you lift your body at each step. Measure in inches and change to fraction of a foot. This number times your weight is the work you do at each step; multiply by the number of steps you take in walking to school to get the foot pounds of work you do. Can you carry this further and find out at what horsepower you are working as you walk to school?

2. **Interesting industries.** Watch the papers and periodicals for articles and pictures of interesting industries. In a short time you can produce a scrapbook full of valuable and interesting information.

SCIENCE CLUB ACTIVITIES

1. **Survey of local industries.** Have different committees for different sections. Find out raw materials, products, handwork, handwork on machines, automatic machines, new inventions, recently introduced. Is the industry an old-time handwork industry with machines replacing laborers or is it an industry that has been created by new inventions? What power is used and how is it developed?

2. **Industrial advantages of your environment.** Try to get the secretary of the Chamber of Commerce or Board of Trade or someone else who is qualified to talk to your club, or have your club sponsor an assembly program in which a talk is presented on "The Advantages Our Community Offers Industry."

3. **Industrial exhibits.** Send to several companies (aluminum, asbestos, rayon, silk, cement, rubber, pencils, glass) and ask if they can supply you with a school exhibit and printed matter about their industry. Prepare a club program in which various industries are explained and the exhibits described.

4. **Automatic machinery.** Visit some plant where the work is largely done by automatic machines. For example, making screws, making electric light bulbs, blowing bottles, canning, packing foods or medicines.

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SURVEY QUESTIONS

What kinds of transportation have you ever seen used?

What do you think are the chief characteristics of a good road?

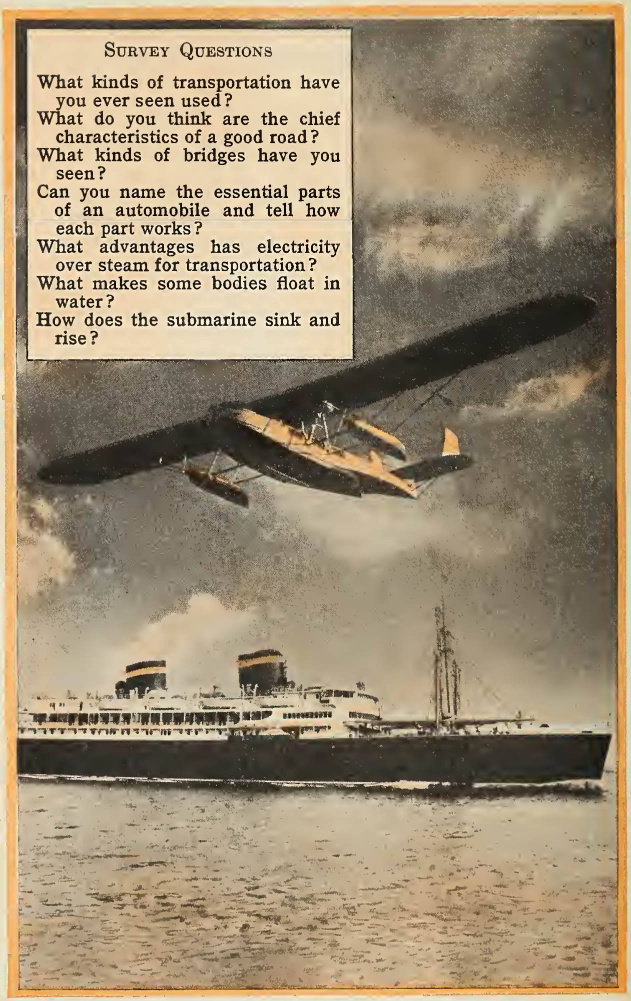
What kinds of bridges have you seen?

Can you name the essential parts of an automobile and tell how each part works?

What advantages has electricity over steam for transportation?

What makes some bodies float in water?

How does the submarine sink and rise?



R. I. Nesmith and Associates

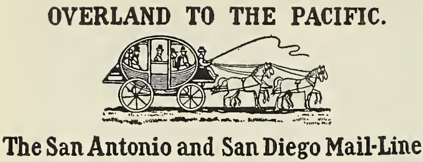
UNIT IX

DEVELOPMENT OF TRANSPORTATION

PREVIEW

Road building is not a new art. The earliest civilizations had good roads, as we find from evidences left by the Aztecs and Mayans on this continent and by the Egyptians and Babylonians on the other side of the ocean. But the Romans were the greatest road builders of ancient times, and some of their highways paved with huge flat stones are still used.

The earliest English settlers in America had no way of travel except on foot. They used the trails of the Indians or cut their way through the forest. It was some years after Virginia was settled that the first horses — only nine of them — were brought from Europe. But it was a great many years later before roads began to take the place of trails. The first roads in America were built largely to help settle new territory and to aid the traders and the farmers in exchanging goods. These roads followed rivers or kept close to the seacoast. An interesting example of this is still seen in the road between Montreal and Quebec, where the St. Lawrence River was at first the only means of communication that the settlers had, the road later being made along the river to connect the little villages. Then came the development of post roads, so that after the close of the Revolutionary War there were 75 post offices and over 2000 miles of post roads. There were few bridges. The larger rivers were crossed by ferries and the smaller ones usually by fords. The first railway line constructed was put into operation about 1807, and others soon followed, so that by 1869, when the two sides of the continent were linked by rails, there were almost 4000 miles of railroads in the United States. Since commodities could be carried for long distances more advantageously on them than on roads, the latter soon became largely local, centering around railroad stations and towns. This condition of roads continued until the automobile began to be used extensively. People soon found that in order to get the best use from these new machines they must have smooth and well-made roads; therefore, state and county taxes were levied so that a splendid system of wide concrete or asphalt surfaced roads is now being constructed in all parts of the United States.

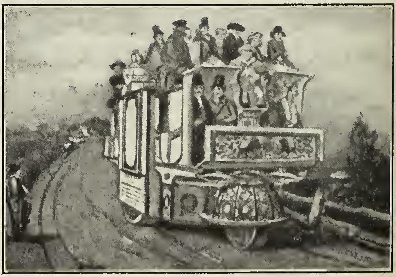

OVERLAND TO THE PACIFIC.

The San Antonio and San Diego Mail-Line

The heading of an advertising circular of eighty-odd years ago.

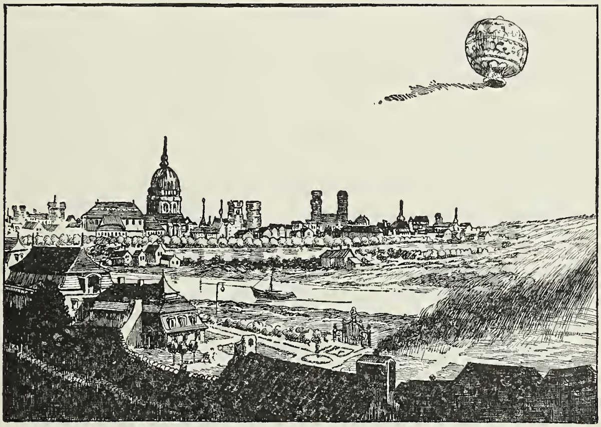
A few generations ago a New York business man who wished to go to Philadelphia chose between a hazardous ocean trip in a small sailing vessel or a tedious two days' journey by stagecoach. Today one makes that journey in comfort in two hours by train or half an hour by plane. In 1843 Marcus Whitman took five months to travel across the continent. Today, New York and San Francisco are less than three days apart by streamlined, Diesel-motored trains or 18 hours by airplane.

A hundred and fifty years ago a month was considered good time for a sailing vessel to make the trip between England and this country. Some of the best liners can make this distance now in less than five days, a recent crossing of the *Rex* being a little less than 4 days, 14 hours.


An early steam carriage. Why were these not successful?

Modern transportation meets the needs of both business and pleasure. A greater revenue comes to boat and railroad lines from carrying freight than from carrying passengers. China has 0.2 mile of railroad per 10,000 inhabitants and only 1.6 miles of railroad to 10,000 square miles of area. There may be rice in abundance in one section of the country, while in another section a million persons may die of famine. The United States has about 250,000 miles of railroad or a little over 20 miles per 10,000 persons or 100 times as much milage per inhabitant as has China. With this network of tracks and fast trains, food can be sent quickly from one state to any other state. With a good transportation system, the surplus of one group of people might satisfy the needs and save the lives of another group at a distance.

We think of the automobile as rather a recent addition to our modes of transportation. The modern development started only forty years ago, but steam carriages were operated on the streets in England a hundred years ago. They were really steam engines covered over, and some of them were equipped with seats for passengers. They belched smoke and steam and frightened horses, so that regulations were made prohibiting their use in the streets. The first real gasoline engine was devised in France in 1862. This engine was the forerunner of the modern automobile engine. It is less than forty years since the modern automobile came into existence, while, today, in this country there are over 24,000,000 automobiles in use. The automobile bus has come to



The Montgolfier balloon over Paris, 1783. From a contemporary engraving.

supplant streetcars and the railroad for short runs, while the auto truck has become an important factor in transportation of goods.

The French were the pioneers in developing balloons. The earliest ones were made by the Montgolfier brothers in 1783, and were called fire balloons, because a straw fire was built under the large bags to supply the hot air which caused them to rise. Later in the same year, hydrogen, which is a gas many times lighter than air, was used to inflate the balloons. Today, with helium gas and great dirigibles, the lighter-than-air machine has come more into the public eye.

But the heavier-than-air machine, dating from the Wright brothers' first flight in 1903, seems destined to the greatest success. Commercial lines for travel, express, and mail are in successful operation and the number of passengers carried is mounting rapidly each year.

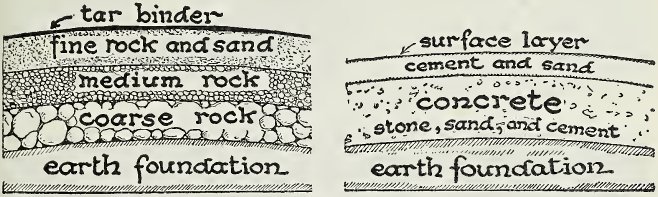
Before beginning the detailed study of this unit, try to recall some of the principles and generalizations that you have already discovered in your previous work. The list that follows will help you to do this.

1. Work is performed in overcoming resistance of any kind.
2. Rolling friction offers less resistance to a force than sliding friction.
3. Heat can be used to produce motion in internal-combustion engines and in steam engines.
4. Electricity produces motion by use of motors.
5. Fluids (liquids and gases) buoy up bodies in them with a force equal to the weight of the fluid displaced.
6. The movement of air against a kite increases the pressure below and decreases the pressure above. This difference in pressure lifts the kite higher in the air.
7. Air resists movement through it.

PROBLEM I. HOW ARE ROADS MADE AND USED?

Types of roads. Although we spend about $1,500,000,000 a year in this country on our roads, we still have over 2,000,000 miles of unimproved roads and less than 1,000,000 miles of improved roads.

The macadam road found in many parts of the country is satisfactory for light traffic. It is made by excavating the road to a depth of a foot or more. Large stones are laid at the bottom and then several layers of smaller stones, each finer than the one beneath it, are laid on. The surface is stone dust bound together

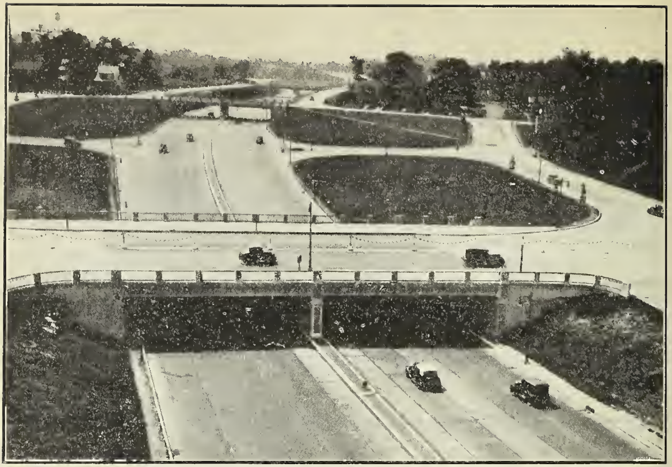


Name these two kinds of roads and give the advantage of each. What modifications of these can you describe?

with bituminous or tar mixtures. Since the macadam road surface is quickly worn through by the auto trucks and swiftly moving busses, our main thoroughfares are now being built of cement or concrete or with a concrete base covered with a tar-mixture surface. The cement road is made by first excavating and laying a deep foundation of concrete. This is covered with a cement surface. It is a better practice to reinforce the cement by embedding within it a network of steel bars which hold the cement from cracking under changes in temperature.

How a Road Wears Out. Heat, cold, and frost may loosen particles in the surface of a road, but traffic does most of the damage. When any vehicle passes rapidly over a road, a partial vacuum is produced behind the wheels, and there is a tendency for outside forces to push the material from the road bed into the vacuum. The continual withdrawal of dust and other small particles finally loosens large fragments, and a road with its surface full of holes is the result. Wheels of large diameter do less damage to a road because they revolve more slowly and pick up less of the material from the road.

Drawing a Load. Do you know why it is harder to start a wagon than to move it after it is started? It requires from two to eight times as much force to start a load as it does to keep it in motion after it is started. This is because of the inertia of the wagon. It is the friction between the wheels and the pavement that makes the movement of an automobile possible.



Ewing Galloway

Modern highway intersections at the New Jersey side of the George Washington bridge. What are the advantages of the overhead crossing?

Wright Pierce

A modern mountain road. At no point is the grade more than 6 to 8 per cent. For what purpose is the stone wall at the roadside?

To lift a weight requires work or energy. Every time a wheel is pulled out of a hole or a rut or goes over a bump, a part of the load borne by that wheel is unnecessarily lifted, and energy is wasted. Thus a rough road requires so much additional energy that a horse or an automobile is able to carry only part of the load that is possible on firm, smooth roads. More work must be done to draw a load uphill than on the level because gravity must be overcome in addition to friction.

Demonstration 1. To Illustrate the Advantage of Large Wheels for Rough and Sandy Roads.

Materials. Spring balance; two small carts, one with wheels of large diameter, the other with wheels of small diameter; a long box of dry sand; weights.

Method. Attach the spring balance to each cart in turn and measure the force required to draw each of these carts, loaded heavily and equally, over the sand.

Conclusion. From the average results of three trials draw a conclusion.

Demonstration 2. To Show the Effect of Different Grades.

Materials. A small cart, a board 3 feet long, blocks to elevate one end of the board, spring balance.

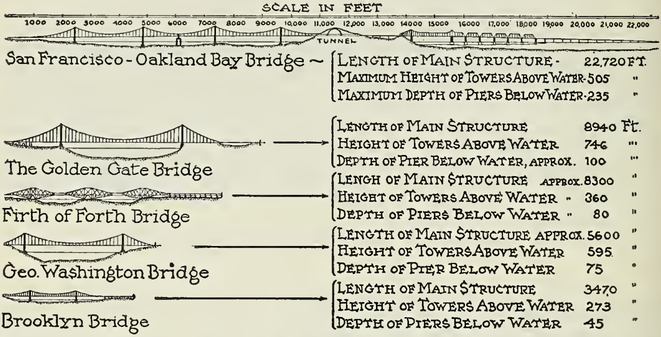
Method. Find the force necessary to draw the cart in these cases.

1. Horizontally
2. When rise is 1 inch in 10 inches. (10 per cent grade)
3. When rise is 2 inches in 10 inches. (20 per cent grade)
4. When rise is 3 inches in 10 inches. (30 per cent grade)

Results and Conclusion. Record the results in a neat table in your workbook. Draw a conclusion and apply it to a practical situation.

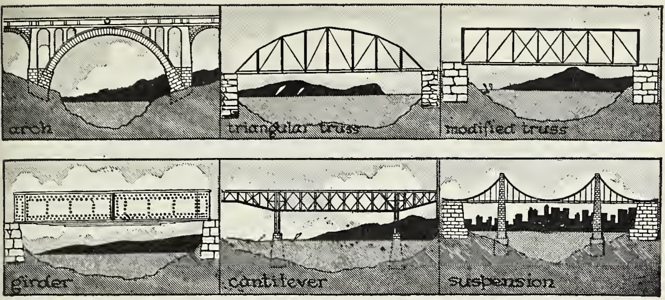
Advantage of Large Wheels. We have learned enough of the lever to understand why a large wheel is better on a sandy or rough road than a small one. Greater diameter of the wheel gives greater leverage, thus requiring less force to move the wheel. As we stated on the preceding page, large wheels do less damage to roads. However, wheels for vehicles drawn by horses must not be so large that the traces attached to the horses are inclined downward, for then part of their power will be lost in pressing the wheels against the ground. Can you explain this to the class by means of a diagram?

Bridges and Their Part in Transportation. Bridges have come into existence only in civilized times. Primitive people when traveling used to ford streams or cross by rafts or boats if the water was too deep. The Romans built bridges of the stone-arch type, many of which still exist in Italy. With the coming of steam and electric railroads and automobiles, bridges have become of much greater importance because they have to carry heavier loads and span longer distances. Consequently, heavier and stronger building materials such as steel girders and cables and concrete piers and abutments have to be used in their construction.


SCALE IN FEET
1000 2000 3000 4000 5000 6000 7000 8000 9000 10,000 11,000 12,000 13,000 14000 15000 16000 17,000 18,000 19,000 20,000 21,000 22,000
TUNNEL
San Francisco - Oakland Bay Bridge ~
LENGTH OF MAIN STRUCTURE - 22,720 FT.
MAXIMUM HEIGHT OF TOWERS ABOVE WATER - 505 "
MAXIMUM DEPTH OF PIERS BELOW WATER - 235 "
The Golden Gate Bridge
LENGTH OF MAIN STRUCTURE 8940 Ft.
HEIGHT OF TOWERS ABOVE WATER 746 "
DEPTH OF PIER BELOW WATER, APPROX. 100 "
Firth of Forth Bridge
LENGH OF MAIN STRUCTURE APPROX. 8300 "
HEIGHT OF TOWERS ABOVE WATER " 360 "
DEPTH OF PIERS BELOW WATER " 80 "
Geo. Washington Bridge
LENGTH OF MAIN STRUCTURE APPROX. 5600 "
HEIGHT OF TOWERS ABOVE WATER 595 "
DEPTH OF PIER BELOW WATER 75 "
Brooklyn Bridge
LENGTH OF MAIN STRUCTURE 3470 "
HEIGHT OF TOWERS ABOVE WATER 273 "
DEPTH OF PIERS BELOW WATER 45 "

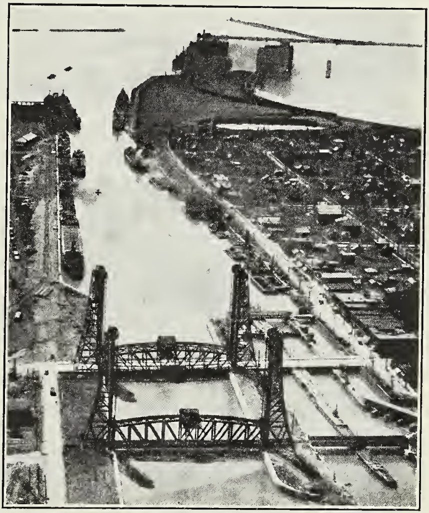
A comparison of modern bridges. Look up in an encyclopedia the dates of completion of the three lower bridges. What progress has been recently made in bridge building?

The Principles on Which Bridges Are Made. A very simple bridge is often seen on country roads. Logs, or perhaps iron beams, are placed across the brook, the ends resting on solid piers. This is known as a *girder* bridge. Such bridges do very well for a short span, but where a long distance must be covered, a bridge must be built so as to hold the load without using such heavy beams. A study of the diagrams shows how this is done by means of what is called the *truss* bridge. The truss is a combination of metal beams, rods, and bars usually put together in the form of a series of triangles so as to form a rigid frame. Because of this construction the truss can support very great weights. Notice how it makes use of the laws of the lever. When still greater distances have to be connected, the principle of the *cantilever* is used. Here we have two



Types of bridges. Can you locate one of each type in your community?

great arms, built like trusses, which project toward each other, the gap between the arms being bridged by a suspended span. The weight of the middle span is held up by two great arms that are anchored on the shoreward ends of the cantilever span, thus balancing the weight of the central span. Other types of bridges with which we are familiar are the *arch*, built of stone or steel, and the *suspension* bridge, in which the weight of the bridge is held up by wire cables which run over towers and are securely fastened on the shore ends in a heavy mass of stone or concrete. The last named is the most graceful bridge of all. A familiar example of the arch is



Canadian Air Force from Ewing Galloway

Lift bridges at Port Colbourne, the Lake Erie terminus of the Welland Canal. How do these bridges operate? What might be an advantage of such a bridge?

the new Hell Gate bridge in New York, while among the most beautiful suspension bridges in the world are the old Brooklyn bridge, spanning the East River, and the new George Washington bridge over the Hudson River. The latter is one of the longest and most expensive suspension bridges in the world, having a length of 8700 feet and costing about $60,000,000.

It often happens that bridges must be built over navigable rivers which have low-lying shores. Here it is impossible to build high bridges under which ships may pass. So a part of the bridge is made movable, to allow the passage of boats. Some of these movable "draws" swing around on wheels or rollers moving on circular tracks. Such are the swing spans of most drawbridges. More modern is the bascule type of span, where a heavy weight at the end of the movable span allows the other end to be raised in the air. Still other types beginning to be used more are the vertical lift bridges, where the whole span is elevated between two towers, or the rolling type, where the movable span is rolled back on rollers at right angles to the waterway.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

friction
less
macadam
partial
inertia
overcome

heat
momentum
lowered
additional
concrete
cold

vacuum
level
loosening
wheels
asphalt
gravity

lifted
force
greater
rough
complete
suction

Two of our best roads are (1)____ and (2)____. Roads begin to wear out from the alternate effects of (3)____ and (4)____, from the (5)____ of surface particles by moving vehicles, and from the (6)____ (7)____ produced behind rapidly rotating (8)____. In starting a load we must first overcome its (9)____. To keep it in motion (10)____ force is required. If the road is level, it is only necessary to overcome (11)____. The (12)____ needed to draw a vehicle up grade is (13)____ than that required on a (14)____ road because the load is being (15)____ against the force of (16)____.

PROBLEM TEST

Suppose you leave Fifth Avenue, New York, in an automobile, cross Central Park, and travel to the Hudson River. You cross the river but not by bridge or ferry. Business takes you to a section of Jersey City where there is much heavy trucking from docks to warehouses. You leave Jersey City, cross the marshes on a new elevated boulevard, pass through the business section of Newark to the residential section of East Orange and along Essex Parkway. You eventually make your way to a distant farmhouse in a sparsely settled part of Pennsylvania.

Describe the character of roads you would expect to find in the different localities and tell why they are adapted to the uses made of them.

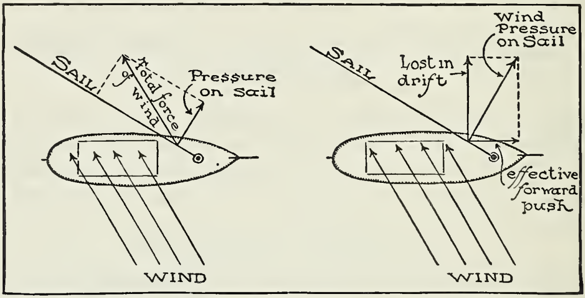
PROBLEM II. HOW IS WATER TRANSPORTATION EFFECTED?

Rowing. The first power device used in water transportation probably was a pole. Then came the paddle. We have read of the wonderful skill of the North American Indian in building and controlling his light birch-bark canoe. But since the paddle would not do for heavy loads, oars came into existence. An oar is used as a lever, applied at the oarlock to the resistance to be overcome, while the blade of the oar acts as a fulcrum. A stroke against the water pulls the boat forward a little; the oar, lifted from the water, is carried back through the air where there is little resistance; and another pull on the oars brings the boat forward again.

How a Boat Is Propelled. When Newton stated the laws of motion, he not only gave us the two that we have discussed in an earlier unit, but he gave us a third law which is stated: *To every action there is an equal and opposite reaction.* This law finds abundant application in the propulsion of boats. If we paddle a canoe or row a boat, the push of the paddle or oar back against the water results in an equal forward push against the paddle or oar. Paddle-wheel boats are moved forward because the paddles act as levers. When a screw or propeller is used in a similar way, the water is pushed back by the same force as the propeller is pushed forward. Since a screw is really an inclined plane which travels in a spiral, it is attached to the boat and the boat itself receives the forward thrust given to the screw.

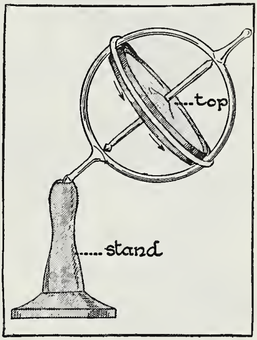
Sailing. With an understanding of the laws of physics came the use of sails. When the wind meets a sail at right angles, its full force tends to act against the sail. When the angle between the wind and the sail is oblique, a part of the wind spills over the side, so that only part of the force of the wind is effective in moving the boat. By shifting the sail and letting the wind work first on one side and then on the other, thus making a zigzag course, it is possible to sail against the wind. This is known as "tacking," as was explained in the Unit on Air.

Steering a Boat. A canoe can be directed in its course by skillful turning of the paddle during the propulsion stroke. When a person rows a boat, another person holding an oar in the water at the stern can determine the course of the boat. Sailboats, motorboats, and large vessels are provided with *rudders*. The rudder is a sort of short broad-bladed paddle, hinged at the stern of a vessel, and connected to a handle known as the *tiller*, which is used to operate it. When the rudder is straight with the keel, the boat goes straight ahead. If the rudder is turned out of this line, it strikes against the water and gives the stern a push in the opposite direction. The bow of the boat turns toward the same side of the keel line as the rudder is turned.



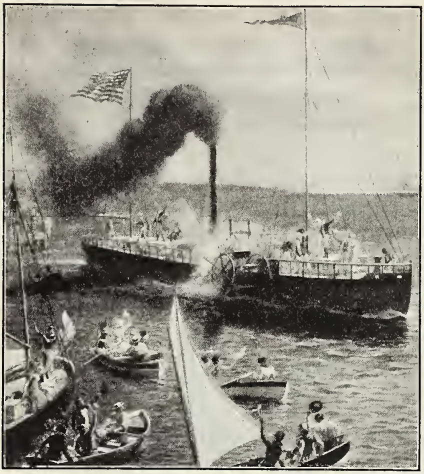
With the wind obliquely ahead, one component of the wind's force may be used to drive the boat ahead. The wind's pressure on the sail is a fractional part of its total pressure, and the effective forward push given to the boat is but a part of the wind's pressure on the sail. How would the sail be placed to run before the wind?

The Gyroscope. A spinning top seems to defy gravity, for as long as it spins it will stand on a mere point. A spinning body offers great resistance to any force which tries to change the direction of the axis about which the body rotates. The tendency of a rotating body to maintain its axis in a fixed position is called *gyroscopic action.* The application of this principle is made in the gyroscope which is used as a stabilizer to prevent ships from rolling at sea. Application of the principle of the gyroscope under the influence of the rotation of the earth has resulted in a gyro-compass, which has practically replaced the magnetic compass on ocean-going vessels. This compass indicates the geographic north pole and is not affected by the magnetic influence of the steel of the ships.



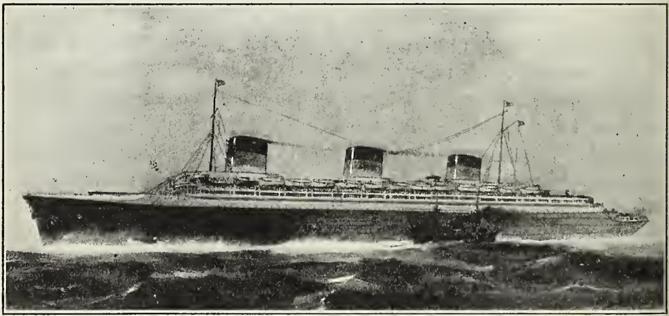
A toy gyroscope.

Use of Steam. In the latter part of the eighteenth century, men began to experiment with steam as a motive power for boats. A man named Fitch rigged up paddles along the sides of a small boat and by means of an engine drove it through the water at the rate of 7½ miles an hour, but it was the good fortune of Robert Fulton to make the first serviceable steamboat. He had become interested in the steam engine, while studying painting in Paris, and in 1803 made a small steamboat which he successfully operated on the River Seine. He tried to enlist the interest of Napoleon in this boat. A committee was appointed to see it work, but on the morning of the trial, Fulton went to the boat and found to his dismay that the heavy engine had broken through the boat and was lying on the bottom of the river. In 1806, however, Fulton purchased an engine in England, built his boat on the Hudson, and announced that on a certain day it would begin its trip to Albany. Crowds of people lined the wharves and the river banks, most of them expecting that the trial would fail, but when they saw the *Clermont,* as it was called, move out under perfect control of the engineer, they realized that a new epoch had begun in transportation on water. The boat made a successful trip to Albany in 32 hours, while the ordinary sailing vessels took about four days. Rapid development of the steamship followed, so that by 1858 we had a record-breaking



The *Clermont*. Robert Fulton's first steamboat was 130 feet long and 16½ feet wide and 4 feet deep below the water line. She made the return trip from Albany to New York, 150 miles, in about 30 hours. How does that time compare with that made by a modern steamboat?

ship for size in the *Great Eastern*, a boat 692 feet long, 83 feet wide, and 58 feet deep. She was driven by paddle wheels and propellers and rendered great service in laying the first transatlantic submarine cable. Unfortunately, she was so far in advance of her time that she was not a success commercially. At the time of the Civil War, iron was first employed in the making of ships' hulls. Now steel has come into extensive use and even concrete is used occasionally. The modern greyhounds, such as the *Queen Mary* and the *Normandie*, ships over 1000 feet in length, give one some idea of the way



French Line

The *Normandie*. The world's largest ship. She is 1029 feet long, 119 feet 6 inches wide, is 36 feet 6 inches deep below the water line, and 128 feet from her keel to the top of the navigating bridge. Compare these measurements with those of the *Clermont*.

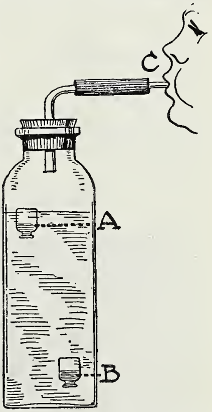
transportation by water has developed. Large vessels have two, three, or four screw propellers, which enable more rapid turning in a limited area. The steam engine, too, has taken wonderful strides. The latest type is the so-called steam turbine, which was first used by Sir Charles Parsons in 1897. With this type of engine, a speed of forty miles an hour is possible, while with an ordinary steam engine twenty-five or thirty miles is the maximum. One serious disadvantage of the turbine is that it cannot be reversed, so that separate turbines have to be made for reversing the ship, unless it is used to generate electricity which operates electric motors, which in turn drive the propellers. Reversal of the electric motors does not interfere with the working of the turbine.

Demonstration 3. To Show How the Submarine May Rise and Sink in Water. (Cartesian Diver.)

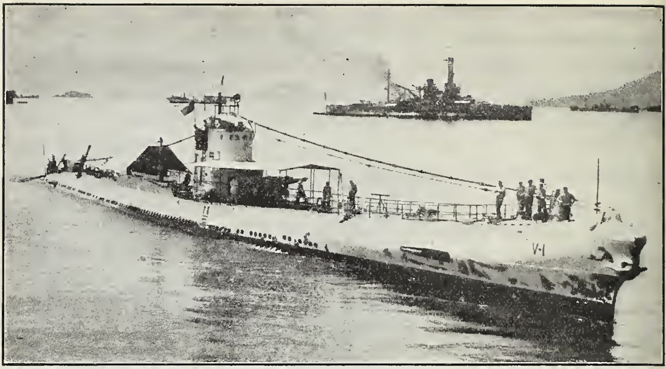
Materials. A glass cylinder fitted with a 1-hole stopper, glass and rubber tubing, two small bottles.

Method and Results. Pass a 3-inch length of glass tubing through the stopper. Attach rubber tubing to the glass tube. Fill the cylinder nearly full of water. Fill the bottles $\frac{1}{3}$ full of water and drop them mouth downward into the water. If they sink, remove enough water from the bottles so that they will just float. Close the cylinder with the stopper and blow through the tube. If the bottles do not sink, add a little more water to them. Change the amount of water in the bottles until they are so adjusted that upon blowing into the closed cylinder the bottles sink, and upon releasing the pressure they rise. By patient trial you can get just enough water into the bottles so that *A* will barely float and *B* will just sink. Watch the change in water space in the bottles.

Conclusion. How would you account for the sinking and rising?



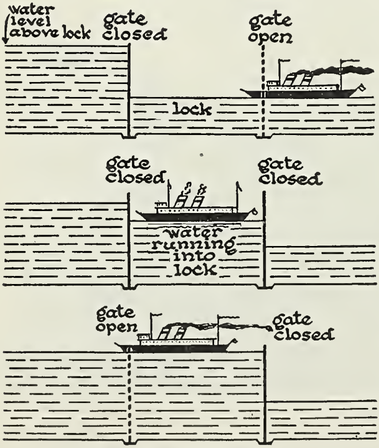
The Submarine. The World War brought the submarine into prominence, and caused its rapid development. A submarine is made so that its weight is a little less than that of its own volume of water. Along its sides are numerous air-tight tanks. Water is admitted to these tanks and forced from them by the use of compressed air. By regulating the



Gendreau

A modern submarine. What do you know about the internal arrangements in this boat? How is such a boat submerged and how is it brought to the surface again?

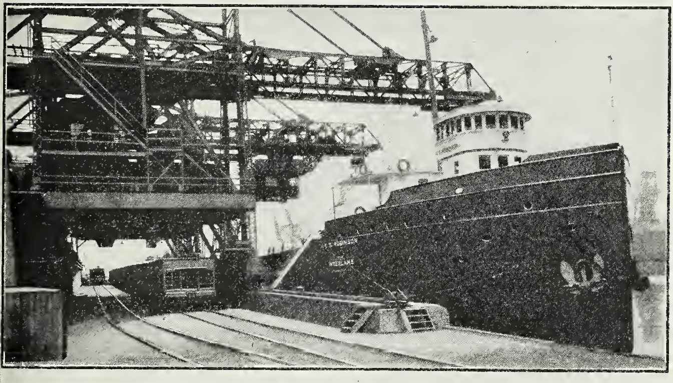
amount of water in these ballast tanks the boat may be made to sink to any depth and come to the surface again. By use of horizontal rudders the boat can be made to dive or come up, depending on the way in which the rudder is operated. When on the surface, the submarine usually employs a Diesel oil engine, and during this time it generates electricity for a large number of storage batteries. When under water it moves by means of the power stored in these cells, which also furnishes current for lighting.


water level above lock
gate closed
gate open
lock
gate closed
gate closed
water running into lock
gate open
gate closed

Explain how a lock works.

Canals as Waterways. In early days before the railroads, rivers were of great importance as a means of transportation. Then came a period, roughly from 1820 to 1840 when canals were built in great numbers, amounting all together to 4468 miles. Most of these canals, however, were destined to failure when the railroads entered into competition with them. Our modern achievement in digging the Panama Canal is one of which we as a nation can afford to be proud. The Welland Canal, recently widened, will now take ocean liners around the rapids and falls in the Niagara River.

Inland Waterways. The development of North America has been greatly influenced by its splendid inland waterways. Not only have we several great river systems navigable for thousands of miles which have been deepened and canalized in spots to form the Chicago to Gulf Waterway, but the chain of the Great Lakes forms a cheap and easy means of transport for ore and grain. In addition, Canada and the United States have built the Sault (Sōō) Saint Marie Canal with locks between Lake Superior and Lake Huron, and the United States has dredged a wide ship channel through the shallow waters of Lake St. Clair. The yearly tonnage through the "Soo" locks is greater than that in any other canal in the world. During the year 1933 the series of canals forming the Great Lakes to Gulf Waterway were opened for through traffic, thus making possible the shipment of goods by water from Chicago to New Orleans.



Ore unloaders at work at the steel mills south of Chicago. What waterways did this boat probably use?

Governments Aids in Navigation. To reduce to a minimum the loss of life and valuable property in ships and cargoes, governments protect boats from possible dangers and have routes carefully charted and marked with buoys. Some buoys are equipped with whistles to warn of danger; some mark channels and are often provided with lights at night. There are great lighthouses which can be seen from a point thirty or forty miles away. Lifesaving stations are located on dangerous parts of our coast, and during a storm men constantly patrol the shore so as to render aid quickly in case of a wreck.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

directly
propellers
pushed
keel
resistance
part
gyro
air
rudder
pulled
fulcrum
water
pressure
submarine
wheels
effort
magnetic
land
obliquely
pushing
tanks
oar
lever
plane

In rowing a boat the oar is a (1)____; the blade in the water is the (2)____; the oarlock, the point of application of the (3)____; and the handle is where (4)____ is applied. In order to make headway against the wind in a sailboat, it is necessary to tack or to hold the sail (5)____ to the wind. In many instances only a small (6)____ of the force of the wind is utilized in (7)____ the boat forward. A (8)____ at the stern of a vessel is used for steering it. In steamships (9)____ are made to revolve in the (10)____ at the stern of the boat, and because the blades are curved so as to push against the water, the boat is (11)____ forward. The (12)____ can float or submerge by controlling the amount of (13)____ in its ballast (14)____. Most modern boats use the (15)____ compass.

PROBLEM TEST

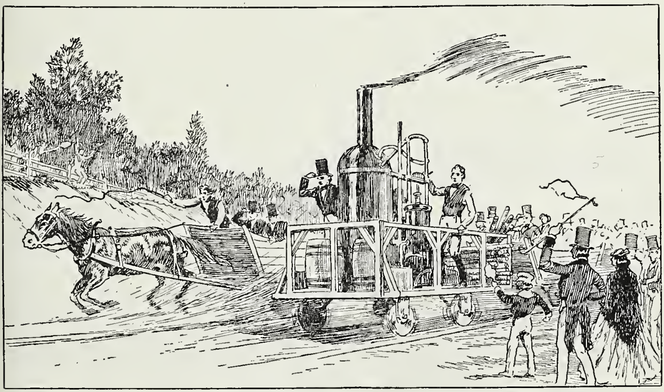
There is a law in science which is sometimes stated, "To every action there is an equal and opposite reaction." *Try to apply this law to transportation by water, giving as much detail as you can in each of the following cases.*

1. In rowing a boat
2. In driving a motorboat
3. In sailing a yacht
4. In using a rudder in steering a motorboat
5. In propelling an ocean liner
6. In elevating a submarine while it is traveling forward through the water

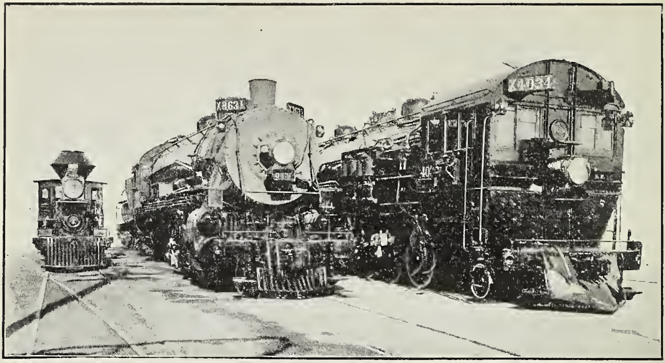
PROBLEM III. HOW DID STEAM TRANSPORTATION DEVELOP IN THE UNITED STATES?

The Use of Rails in Transportation. The first methods of transportation made use of roads with stone or earth foundations, but, some hundreds of years ago, it was found that much larger loads could be pulled along tracks or on wooden rails. In 1738 the first iron rails were used. The advantage of rails for land travel was at once apparent, and, from the first, all serious consideration of steam travel assumed a rail system soon developed all over the country.

The Development of Railways in the United States. The first railroad in the United States was built in 1826 from the granite quarries in Quincy, Massachusetts, to the seacoast. This road was only four miles long, and the cars were hauled by horses. The first locomotive to be operated in America was the Stourbridge Lion,



The first locomotive built in America was the Tom Thumb. On its return from a trial trip on August 28, 1830, the race shown here took place and the little engine was beaten.



Southern Pacific Railway Co.

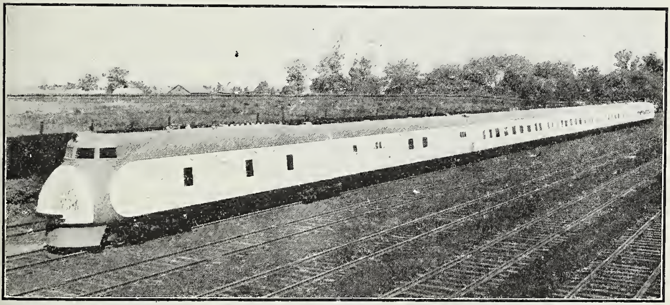
Sixty years' locomotive development. The left-hand locomotive went into service early in 1864, the two at the right are in use today and are three times as long and twenty times as powerful as the one used sixty years ago.

imported from England, and run August 8, 1829. The first locomotive was built in England in 1803 by Richard Trevithick, but it proved a failure. The first railway opened to the public was operated in Charleston, South Carolina, and the train was drawn by the "Best Friend," which was not considered a "best friend" by all the passengers, for it belched out black cinders and live sparks, setting fire to their umbrellas and clothes. By 1861, there were 30,000 miles of railroad built in the United States, and at the present time there are about 250,000 miles of railway with 90,000 locomotives, 60,000 passenger cars, and nearly 3,000,000 freight cars.

The Locomotive Engine. The locomotive may be called the traveling or moving steam engine. If you mount an engine, a boiler, and a furnace on wheels, you have the essential parts of a locomotive. The first successful locomotive was built by George Stephenson, an English engineer. He used the principle of Watt's engine. His first successful use of the engine was in 1814, when he hauled coal cars at the rate of four miles an hour. The first passenger train traveled at the rate of fifteen miles an hour, drawn by a locomotive less than 20 feet long and weighing a few thousand pounds. Today a modern passenger locomotive is over 90 feet long, weighs over 700,000 pounds, and draws a train of ten or twelve cars at a speed of a mile a minute. You will notice that some locomotives have larger driving wheels than others. Freight engines which draw heavier loads have small driving wheels, while passenger engines built for speed have large ones. Can you tell why there should be this difference?

The Development of Passenger and Freight Service. Those who visited the Century of Progress remember the comparison of the early passenger cars with the luxurious equipment of the modern passenger trains. Air conditioned, properly heated and ventilated, with observation, library, sleeping, and dining cars of aluminum and steel, they showed the last word for comfort in travel. But equally important advances have been made in freight service. Not only do we have refrigerator cars, built to carry perishable freight, such as fruits and meats, but we find great glass-lined tank cars built to carry milk, so well insulated that chilled milk can be placed in the tanks and delivered 48 hours afterward without gaining a degree of heat. Tank cars have revolutionized the shipping of milk in this country. Milk has been shipped from Wisconsin to Miami, Florida, the shipment taking 4 days and 5 hours, and the milk being received in perfect condition. Other types of tank cars are built to carry oil, cement powder, and other commodities, while the United States Government has one type of tank car in which it ships helium gas, used in its dirigibles, from its place of manufacture to the various hangars where the dirigibles are stationed.

Streamlined Trains. We hear a good deal today about the advantages of streamlining in automobiles, airplanes, and railway



R. I. Nesmith and Associates

This train cut off a day in running time between Los Angeles and Chicago. What do you know about it?

trains. The streamlined train which made the new transcontinental record had the additional advantage of lightness in weight. This train of six cars built of aluminum alloy weighed 211 tons instead of 700 tons for a steam train of the same size. It has a lower center of gravity and attained a speed of over 120 miles an hour. On October 25, 1934, it reached New York after having made the trip from Los Angeles in 56 hours and 55 minutes. The train was provided with a 900-horsepower V type 12-cylinder Diesel engine, the first to be used in high-speed passenger service.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces on the sentences below and arrange them in proper numerical order. The same word may be used more than once.

airships
grade
transportation
France
heavier
perishable
power
hydrogen
insulated
rails
Germany
1829
wheels
smaller
America
airplane
England
tank
breakable
milk
speed
steamboat
oxygen
passenger
last
first
helium
locomotive
1800
built
1850
1920

With a given force (1)____ loads can be hauled on (2)____ than on ordinary roads. The first locomotive to be operated in America was built in (3)____ and first used in this country in (4)____. The "Tom Thumb" was the (5)____ practical locomotive (6)____ in America. Freight engines have (7)____ (8)____ than (9)____ engines. The (10)____ wheels give the freight engine greater (11)____.

Great progress has been made in (12)____ of commodities. Refrigerator cars are built to carry (13)____ freight. These cars are well (14)____ to control temperature. (15)____ cars transport commodities like (16)____, oil, and cement powder. The United States government has a special type car which transports (17)____ gas used in (18)____ from its place of manufacture to the hangars.

PROBLEM TEST

What are the advantages of passenger and freight transportation by railroads and by motor vehicles (busses and trucks)?

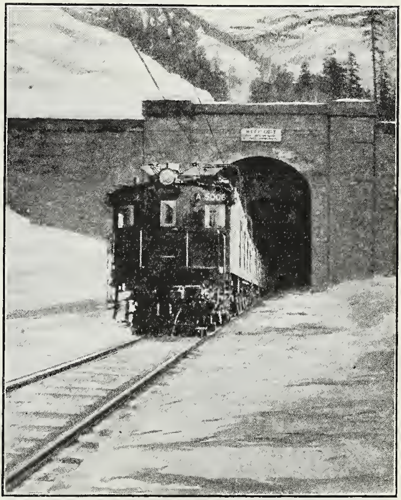
Why do the railroads claim that the motor vehicles make unfair competition?

PROBLEM IV. HOW DID ELECTRIC TRANSPORTATION DEVELOP?

Electric Railways. Hundreds of thousands of people use the electric cars either on the streets, in the subways, or on the elevated roads. Electric cars came into use about 1890. For street service they are now rapidly being replaced by the automobile busses, which run more quietly and require neither track nor wires.

The Electric-car Circuit. Electricity is conducted from the generator in the power station to the trolley wire, which is usually placed underground, through the trolley to a number of controlled resistances, and then to the electric motors beneath the car. The motorman, by moving the controller handle, determines just how much resistance is to oppose the electricity, and thus he regulates the amount of current which passes through the motor. The current passes from the motor through the wheels of the car to the rails, and is conducted by the rails and ground back to the generator in the power house, thus completing the circuit. We have learned that electricity can do no work unless there be a complete circuit from its source out through the wires, motors, or other instruments, and back to its source again.

In subways or elevated systems, and in some cross-country runs, a third rail takes the place of a trolley wire. This rail must be insulated from the ground. A person who stands on the damp ground and accidentally touches the third rail is almost



Great Northern Railway

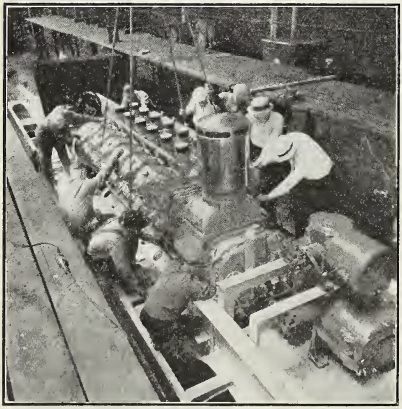
Read your text and find out why electricity is used in these mountain areas.

certain to be killed because the ground acts as a return conductor.

The Replacing of Steam by Electricity. In many parts of the country electricity is taking the place of steam power to propel locomotives. Steam locomotives are not very efficient in their use of coal, as it takes a large amount of coal to furnish the necessary amount of power. In some parts of our country, coal is not obtained as easily as water power, which is harnessed to produce electricity by means of great generators. Consequently, it is much cheaper, because water power is usually abundant where railroads have to go up heavy grades.

When there is a long upgrade and a long downgrade the other side of the crest, gravity is sometimes utilized for power. The train going downgrade runs by gravity and the motor acts as a generator to produce an electric current which can be turned into the trolley wire to help a train on the upgrade. Another advantage is that it supplies an effective brake, just as in the automobile, when we put the engine in low gear.

Gas-electric Cars and Busses. The rapid development and use of the automobile have seriously affected the income of the steam and electric railways. In their effort to reduce the expense of equipment and operation, the gas-electric cars are being introduced for service where traffic is light. One end of the car is given up to the power plant. A gas engine or a Diesel engine drives a generator which gives the electric current for operating the car. The use of electricity rather than the gas engine alone gives more flexibility in handling



Union Pacific

The 900-horsepower, V type Diesel engine which was used in the first transcontinental run which cut off one day in running time between Chicago and the Pacific coast.

and lessens the cost of operation of the car. Because of the greater ease in handling, large busses are now using this combination of gas and electric power. The Diesel engine is used in the streamlined trains that are making such rapid time on our western railroads today. On the first record run of this train in October, 1934, the train averaged one mile on 1.6 gallons of oil, costing 4 cents a gallon. It is said the transcontinental run cost less than $80 for fuel.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

flexibility
Diesel
speed
handle
generator
momentum
resistance
volts
steam
station
oil
motor
cost
inertia
rails
power
gravity
trolley
ground
controller
electricity
gas
electric
energy

The electric (1)____ is the machine that drives our trolley cars. Current comes along the (2)____ wire from the (3)____ in the (4)____ house to the (5)____ in the car; then it goes back through the (6)____ and (7)____ to the starting point. The motorman changes the speed by use of the (8)____ (9)____ which changes the (10)____ in the circuit. (11)____ locomotives are replacing (12)____ locomotives. On a long downgrade, electric trains make use of (13)____ for power. At such a time the motor acts as a (14)____ to produce (15)____ for use on the upgrades. The gas-electric car uses a (16)____ or (17)____ engine to generate electric current. The use of (18)____ with the gas engine makes for greater (19)____ in handling and lessens the (20)____ of operating the car.

PROBLEM TEST

A power house in a certain city supplies electricity to electric cars which run in part upon city streets, in part in subways, and in part upon elevated structures. In the street there are overhead trolley wires. In the subways there may be trolley wires and a third rail. The elevated road has only a third rail to supply the cars with electricity. The electrons that are sent out from the power house to run these cars must return to the power house again.

Trace the paths traversed by the electrons in each of the three systems in making a complete circuit from the generator in the power house back to the generator again.

PROBLEM V. HOW DID THE AUTOMOBILE DEVELOP?

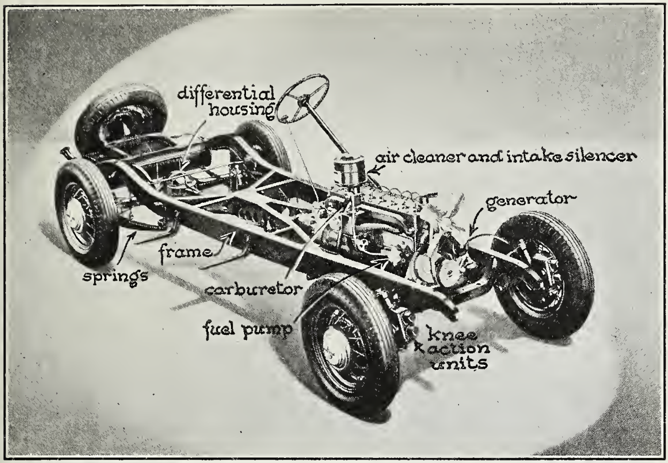
The Parts of an Automobile. The progress in transportation has been made possible largely by the construction of automobiles and trucks, which in turn were made possible by the invention of electrical devices, the gasoline engine, and the development of strong and tough steel alloys. There are four important parts in the motor car: the *chassis* (shȧ′sē), the *power plant*, the *transmission mechanism*, and the *electric system.*

The Chassis. The chassis includes the framework and the wheel controls, such as the steering gear and brakes. The frame is made of chrome nickel steel or vanadium steel. Springs on the frame support the body of the car. The speed of the machine is retarded or stopped by tightening a brake band around the brake drum on the wheels. One brake is operated by the foot, and the emergency brake, in the form of a lever, is operated by the hand. By means of these brakes the driver is able to increase the friction on the drums and thus lessen the speed of the car.

Demonstration 4. How Brake Bands Stop the Wheels.

Secure a small motor with a wheel on the shaft; a toy motor may be used. Prepare a brake by fastening the ends of two strips of wood so that they are slightly less than the diameter of the wheel about it. Start the motor; place the strips of wood one above and the other below the rotating wheel. Press them together. Produce friction on the outer rim of the wheel. Notice the change in speed as the friction is increased by greater pressure.

The Power Plant. The power plant consists of the engine and its accessories. The gasoline supply is held in a large tank from which a pipe leads to the carburetor. If the tank is higher than the carburetor, the gasoline flows to it by gravity; if it is lower, gasoline is first drawn into an elevated vacuum tank, from which it flows by gravity to the carburetor. The carburetor vaporizes the gasoline and mixes it with air before it goes into the engine. The working of the gas engine has been explained on pages 145–147. You

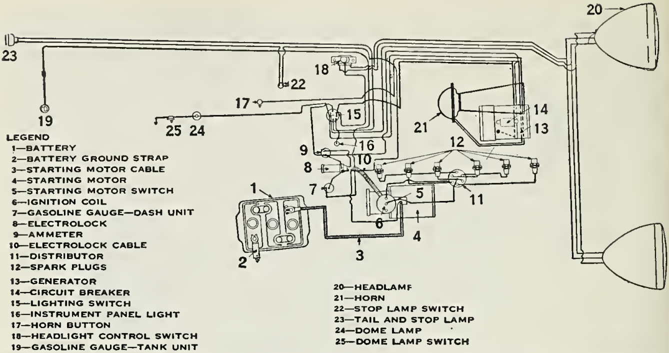


The chassis of a modern car. How many of the labeled parts can you give the use of? How many parts are explained in the text?

should review this material at this time. The burnt gases from the engine pass to the muffler, which reduces the pressure and noise from the discharge of the gases by allowing them to escape at a pressure little greater than that of the surrounding atmosphere.

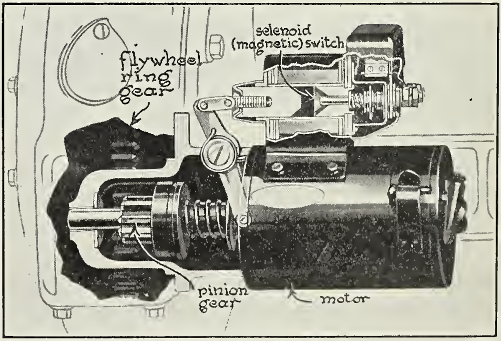
The Electric System. There are four uses of electricity in the car: to sound the horn, to light the lamps, to produce the spark for ignition in the engine, and to drive the motor which starts the engine. This electricity is obtained from a generator operated when the engine is running, which transforms the mechanical energy of the engine into electrical energy. The generator charges a storage battery which is the direct source of current for the various purposes mentioned above.

High voltage is required to produce a spark. The storage battery usually gives only six volts, but by passing this current into an induction coil the induced current coming from the coil is at high pressure. This high-pressure current is carried by copper wires, well insulated in heavy rubber covering, to the spark plugs. The spark must be produced in each cylinder at just the right instant; this is accomplished by the timer.


20
23
18
22
17
15
14
19
25 24
21
13
12
9
16
10
8
7
1
5
11
6
4
2
3
LEGEND
1—BATTERY
2—BATTERY GROUND STRAP
3—STARTING MOTOR CABLE
4—STARTING MOTOR
5—STARTING MOTOR SWITCH
6—IGNITION COIL
7—GASOLINE GAUGE—DASH UNIT
8—ELECTROLOCK
9—AMMETER
10—ELECTROLOCK CABLE
11—DISTRIBUTOR
12—SPARK PLUGS
13—GENERATOR
14—CIRCUIT BREAKER
15—LIGHTING SWITCH
16—INSTRUMENT PANEL LIGHT
17—HORN BUTTON
18—HEADLIGHT CONTROL SWITCH
19—GASOLINE GAUGE—TANK UNIT
20—HEADLAMP
21—HORN
22—STOP LAMP SWITCH
23—TAIL AND STOP LAMP
24—DOME LAMP
25—DOME LAMP SWITCH

This shows a wiring diagram of the electric system in a passenger car. Follow the wiring in one direction from the generator to the battery and then from the battery to the various parts of the car where electricity is used. Name all these parts of the car, their location, and their uses.

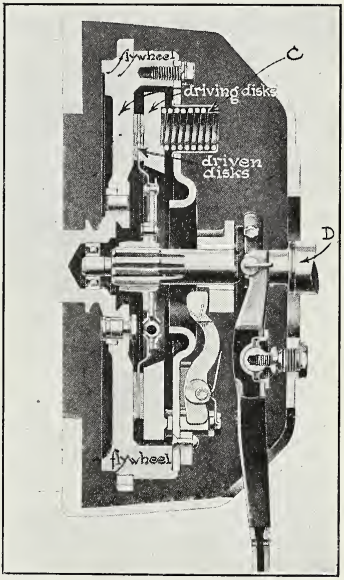
The Starter. To start the engine the shaft must be turned until some one cylinder has received a charge, the charge has been compressed, and then set off by the spark. This produces power to keep up the motion until other cylinders give power. A self-starting mechanism is used for this purpose although the start can be given by cranking. The self-starter is a small motor which


selenoid (magnetic) switch
flywheel ring gear
pinion gear
motor

The self-starting mechanism of a modern passenger car. Try to explain how it works.

engages the shaft of the engine and "turns it over." When the engine starts under its own power, it automatically disconnects contact with the self-starting motor. In some cases the generator for charging the battery is operated as a motor to start the engine.

Transmission. Before an automobile can move, the power developed in the engine must be transmitted to the wheels. This is done by the clutch which connects the revolving crank shaft to the shaft drive, which in turn transmits the power to the driving wheels of this car. There were formerly two types of clutches used, *cone* and *disk*, but the latter has come into general use in recent years. The disk clutch allows the engine to pass on power to the transmission through the use of disks, whose relation can be understood by a study of the accompanying diagram. Attached to the inside of the flywheel are a number of driving disks; alternating with these are driven disks which communicate the power by means of the shaft *D* to the transmission gears. The spring *C* holds the driven disks firmly against the driving disks, and engine power is carried to *D*. The shaft *D* passes into the transmission case, where, by various gears, different powers or speeds may be applied to the propeller shaft which runs from the transmission case to the rear axle. Here the power is given to the driving wheels. But when the foot presses on the pedal, spring *C* is compressed, and the driven disks are pulled away from contact with the driving disks, allowing the engine to run freely without communicating power to the shaft *D*. Even with shaft *D* running, the gear shift lever

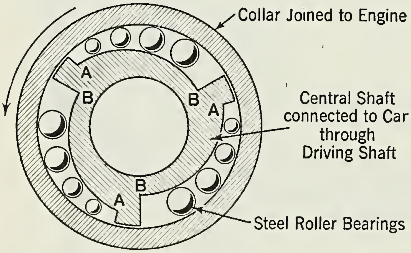


Study the diagram, read the text, and then explain how the transmission works.

may be placed in neutral and there will be no transmission of driving force to move the car.

The Differential. When a car goes around a corner, the wheels on opposite sides of the car mark off two concentric circles of unequal radii. The outer wheel must go faster than the inner one. If both wheels were on the same shaft, turning at the same speed, there would be severe wear on the tire of the inner wheel. A very important device called the *differential* makes it possible for these wheels to turn independently of each other. The device is rather complicated, but has a series of gears which mesh with the gears from the rear end of the drive shaft and communicate the energy through the rear axles to the two driving wheels. A few cars are made with front-wheel drive, but the great majority have the driving force given to the car by the rear wheels.

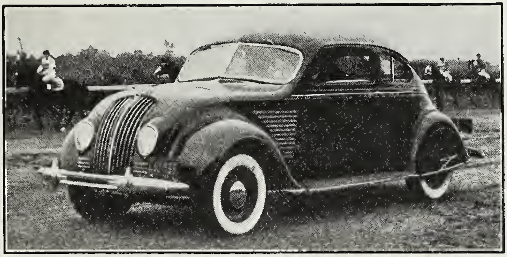
Free Wheeling. You are doubtless familiar with the coaster-brake bicycle. You apply power by pedaling for a while, but after you get up speed you may stop pedaling and coast. In going down hill, you coast likewise, and back-pedal to put on the brake as your speed gets too great. A similar free-wheeling device is used to permit automobiles to coast down hill or along a level without releasing the clutch. With the conventional drive, one can press the clutch pedal and coast, but much use of the clutch for this purpose brings undue wear to the clutch surfaces. When the lever of the car is set for free wheeling, the engine turns the driving shaft as long as its speed is at a lower speed than that of the engine. When the car is going at high speed, and the engine is slowed down, the driving shaft is allowed to turn independently of the engine. This is commonly true when one goes down hill. The engine, in this case, does not act as a brake as it does with the conventional drive.



The free-wheeling mechanism in a modern car. Under what conditions will the balls become wedged between the collar and shaft and cause the two to rotate together.

The free-wheeling mechanism consists of a central shaft, which drives the car, and an outside collar joined to the engine. Between the two are three tapered slots containing steel roller-bearings of graded diameter. When the collar has a higher speed than the central shaft, the rollers are moved to the small end of the slot, and they act as wedges and cause the shaft to move with the collar. When the engine moves more slowly than the shaft, the rollers are moved back to the wider part of the slot, and the shaft turns independently of the collar.

The Modern Car. Not only are there improvements in transmission, in brakes, and in devices which give greater latitude, as free wheeling, but much has been done to add to one's comfort. Air currents which circulate inside the car are within control. Individual wheel action, allowing a wheel to rise over an obstacle without raising the car, is effected by the so-called "knee action" principle. Automatic gear shifting has been developed so if you choose it is no longer necessary to have a gear-shift lever. The streamline models decrease the wind resistance, which is a large factor when one travels at high speed. Streamlining makes operation somewhat more economical.



The modern car is often streamlined. Why would streamlining be advantageous in rapid driving?

Tractors and Their Uses. In late years the gas engine has come into prominence on the farm, where it does the work of plowing, sowing, reaping, and threshing better and more economically than was done formerly by horses. The World War made use of tractors in dragging heavy guns and supplies. The tank or so-called caterpillar tractor became an important weapon of offense; it went over the roughest kind of ground, tore up barbed-wire entanglements, and even passed through heavy embankments and walls of masonry. Today the tractor is used on the farm, in road making, in clearing rough areas, and in many other ways.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

engine
carburetor
wheels
coil
tin
timer
eight
gears
friction

differential
brake
vanadium
automobile
around
voltage
discharged
battery
induction

transmission
runs
aluminum
six
induction
inertia
drums
driven
steel

generator
storage
charged
motor
four
clutch
chassis
drum
electric

The frame of the (1)____ of the automobile is usually made of unbreakable metal as chrome nickel (2)____, or (3)____ steel. Brake (4)____ are attached to the wheels. When the (5)____ band is tightened around this (6)____, the added (7)____ slows the car. The flywheel always (8)____ when the (9)____ is going, but unless the (10)____ is engaged, no power can be transmitted to the driving wheels. The transmission (11)____ pass on this power. The (12)____ battery usually gives a current at (13)____ volts. The higher (14)____ required for ignition is secured by use of an (15)____ (16)____. The battery is (17)____ by means of a generator driven by the (18)____. The generator may also act as an (19)____ (20)____ for starting the engine.

PROBLEM TEST

The automobile in action is a great power plant in which many kinds of changes are constantly going on. *Think over the different kinds of changes matter undergoes. Think over the various transformations in energy. See how large a list of each you can make. Classify under these headings:*

1. *Physical Changes.*
2. *Chemical Changes.*
3. *Transformation of Energy.*

PROBLEM VI. AIR TRANSPORTATION

Airplane products in the United States are now valued at about $100,000,000 yearly, and in 1933 there were almost 10,000 air craft in use. These facts are evidence that air transportation has become established as a means of conveyance. The construction of airplanes has been perfected to such a degree that with competent pilots the risk of riding in the air is not much greater than in other modes of travel. The success in making highways in the air has been reached by long, hard work on the part of many hardy, fearless men. There are two types of air machines: one, such as the balloon and airship, is the *lighter-than-air;* and the other, such as the airplane and hydroplane, is the *heavier-than-air.*

Why Balloons Rise and Float. A balloon rises because it is pushed up by the air which is denser than the gas in the balloon. Hence only those gases which are lighter than air can be used. The higher the atmosphere, the less is its lifting power, because its density decreases as we go upward. When a balloon has risen until its total weight equals that of the air it displaces, it ceases to rise, and becomes a floating body, very much like a boat.

Demonstration 5. To Discover What Common Gases Are Lighter Than Air.

Collect two test tubes each of carbon dioxide, oxygen, hydrogen, and illuminating gas as follows:

1. *Carbon dioxide.* Put some chips of marble in the generator; add dilute hydrochloric acid. Close and collect gas by the displacement of water.
2. *Oxygen.* Heat equal portions of potassium chlorate and manganese dioxide in a test tube and collect in a bottle the gas given off, by displacing the water.
3. *Hydrogen.* Pour dilute sulphuric acid upon zinc in a generator and collect the gas by displacing the water.
4. *Illuminating gas.* Connect a rubber tube to a gas cock and collect the gas as in other cases.

Method. Hold one tube of each gas mouth down for one minute and apply test for the presence of the gas. Hold another tube of each gas mouth up for one minute and apply test for the presence of the gas. Test with lighted taper. Flame is extinguished in carbon dioxide. It burns brighter in oxygen. Hydrogen explodes sharply. Illuminating gas gives slight explosion or burns.

Results. Which gases are found to be lighter than air? How do you know that they are lighter?

Application. Name some practical use of a gas depending upon its lightness.

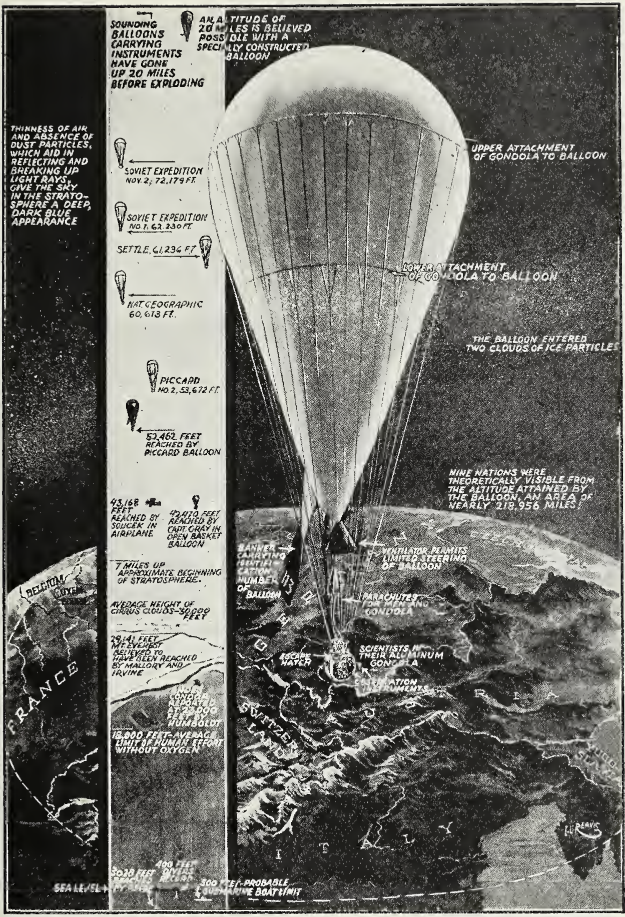
Buoyancy of air holds up objects in the sea of air just as water holds up objects which weigh less than the amount of water displaced. Hydrogen being many times lighter than air is useful for airships; but because of its inflammability, it introduces danger of fire. With helium, a gas slightly heavier than hydrogen but lighter than air, the danger of fire from lightning or from the engine is removed. A thousand cubic feet of air weigh 80 pounds, and a thousand cubic feet of helium weigh only 22 pounds. Therefore helium has a lifting power of 58 pounds per thousand cubic feet. A balloon carrying 200,000 cubic feet of helium has a lifting power of 200×58 or 11,600 pounds. In the airship, a part of this lifting power is used to hold up the material of the bag and the car, and the rest is used for freight and passengers.

Demonstration 6. Buoyancy of Hydrogen.

Make a thick soap solution with which you can blow large bubbles. Attach a glass tube with smooth fire-polished edge by means of a rubber tube to a gas jet or to the delivery tube of a hydrogen generator. By pressure on the rubber tube the flow of gas may be regulated.

Blow bubbles with the gas. Shake off. Observe: (1) Some rise directly. Explain why. (2) Others sink at first, and then rise. Watch these carefully. Try to discover the cause of this action. How does this illustrate the practice of throwing out ballast?

Uses of Balloons. Balloons are not of much value for transportation, for they depend entirely upon the wind currents. A skilled balloonist, by shifting the altitude of his balloon, is able to take advantage of wind moving in different directions. Balloons for sounding purposes carrying instruments have risen nearly twenty-four miles above the earth. The temperature there is − 60° F. and the pressure $\frac{1}{250}$ of that at the surface of the ocean. On August 18, 1932, Dr. Auguste Piccard rose to a height of over ten miles in a balloon to which was attached a hermetically sealed spherical gondola. Since then both Russian and American scientists have risen to heights shown on the opposite page. They all


SOUNDING BALLOONS CARRYING INSTRUMENTS HAVE GONE UP 20 MILES BEFORE EXPLODING
AN ALTITUDE OF 20 MILES IS BELIEVED POSSIBLE WITH A SPECIALLY CONSTRUCTED BALLOON
THINNESS OF AIR AND ABSENCE OF DUST PARTICLES, WHICH AID IN REFLECTING AND BREAKING UP LIGHT RAYS, GIVE THE SKY IN THE STRATOSPHERE A DEEP, DARK BLUE APPEARANCE
UPPER ATTACHMENT OF GONDOLA TO BALLOON
SOVIET EXPEDITION NOV. 2; 72,179 FT.
SOVIET EXPEDITION NO. 1, 62,230 FT.
SETTLE, 61,236 FT.
NAT. GEOGRAPHIC 60,613 FT.
LOWER ATTACHMENT OF GONDOLA TO BALLOON
THE BALLOON ENTERED TWO CLOUDS OF ICE PARTICLES
PICCARD NO. 2, 53,672 FT.
53,462 FEET REACHED BY PICCARD BALLOON
NINE NATIONS WERE THEORETICALLY VISIBLE FROM THE ALTITUDE ATTAINED BY THE BALLOON, AN AREA OF NEARLY 218,956 MILES!
43,168 FEET REACHED BY SOUCEK IN AIRPLANE
42,470 FEET REACHED BY CAPT. GRAY IN OPEN BASKET BALLOON
BANNER CARRYING IDENTIFICATION NUMBER OF BALLOON
VENTILATOR PERMITS LIMITED STEERING OF BALLOON
113
7 MILES UP APPROXIMATE BEGINNING OF STRATOSPHERE.
PARACHUTES FOR MEN AND GONDOLA
AVERAGE HEIGHT OF CIRRUS CLOUDS—30,000 FEET
29,141 FEET MT. EVEREST BELIEVED TO HAVE BEEN REACHED BY MALLORY AND IRVINE
ESCAPE HATCH
SCIENTISTS IN THEIR ALUMINUM GONDOLA
OBSERVATION INSTRUMENTS
BELGIUM
FRANCE
CONDOR REPORTED AT 23,000 FEET BY HUMBOLDT
18,000 FEET—AVERAGE LIMIT OF HUMAN EFFORT WITHOUT OXYGEN
SWITZERLAND
ITALY
400 FEET DIVERS RECORD
SEA LEVEL
300 FEET—PROBABLE SUBMARINE BOAT LIMIT

Courtesy Popular Mechanics

A careful study of this picture will give you many facts about the Piccard flight as well as others. These facts have been brought down to the fall of **1934**.

made many interesting scientific observations and reached the greatest altitudes ever attained by man.

The Airship. For a great many years people worked on plans to steer balloons. Captain Renard of the French army in 1885 was the first man to bring his cigar-shaped balloon back to its starting point. Santos Dumont in 1901 won a $20,000 prize for steering his airship a distance of about seven miles around the Eiffel Tower and back to his starting point, in less than half an hour. It is interesting to know that he used an automobile engine. The automobile, therefore, helped in the development of the airship. Count Zeppelin of Germany first made a rigid airship containing a large number of sections, each one of which was a distinct balloon by itself, and the entire lifting body of the balloon was made rigid by means of aluminum bars and rings. The commercial possibilities of airships seem to be rather great, although the rate and safety of the craft is dependent on winds and storms. The English dirigible, *R34*, in July, 1919, made the first trip from Europe to America; the return, with favoring winds, was made in only a little over seventy-five hours. In 1929, the airship, *Graf Zeppelin*, carried freight and passengers around the earth in 20 days 4 hours running time and since then has made many long trips. Airship service is maintained between Germany and South America.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

rigid
iron
balloon
equals
gas
wind

flexible
hydrogen
denser
liquid
floats
nitrogen

aluminum
helium
airplane
oxygen
displaces
directed

airship
hotter
steel
sections
machine
lighter

The buoyancy of balloons and airships depends upon the use of a (1)____ which is (2)____ than air. A balloon rises because it is pushed up by the air which is (3)____ than the (4)____ in it. When the total weight of the balloon (5)____ that of the air it (6)____, for it cannot rise further. The gas which has the greatest lifting power is (7)____ and (8)____ comes next. Danger from fire is removed when (9)____ is used instead of (10)____ to give buoyancy to airships. Count Zeppelin of Germany first made the (11)____ airship. This was accomplished by using (12)____, each one a separate (13)____ in itself, and fastening them together by (14)____ bars and rings. Commercial transportation finds the (15)____ more useful than the (16)____ because it can be (17)____ against the (18)____.

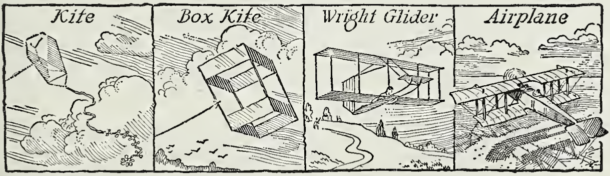
PROBLEM TEST

What are the opposing forces that are involved in each of the following movements of a balloon and how do you explain the resultant action?

1. When a balloon rises.
2. When a balloon moves horizontally in the air.
3. When a balloon descends.

PROBLEM VII. HOW DOES THE AIRPLANE STAY UP AND FLY?

The Invention of the Airplane. Like many other great inventions, the airplane is not the work of any one man, although Americans have had a prominent place in developing it. In 1900, the Wright brothers began experimenting with gliders, and learned much about the laws of flight. In the early attempts to keep the airplane and gliders stable, the operator would move his body one way or the other, depending which way the machine was tilting. The Wright brothers advanced aviation to a remarkable degree by their epoch-making discovery that the airplane could be kept on even keel by warping the wings, or by constructing small winglets at the ends of the wings operated by levers and wires. The secret of their being the first to fly successfully was their invention of a



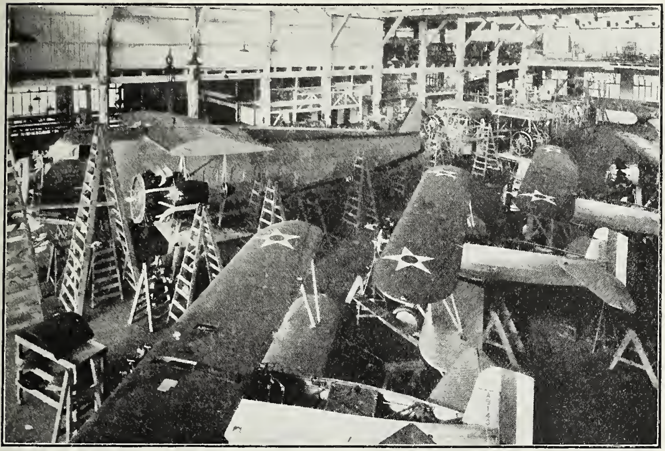
Explain with reference to these diagrams how the airplane came into existence.

device whereby one movement of a lever would flex the rear end of the planes and operate the vertical rudders. Successful flying depends upon the two changes being made simultaneously. In 1903, they placed a gasoline engine on their glider and made exhibition flights of a minute in duration.

The rapidity with which improvements in the airplane have been made can be realized when we recall the successful flights across the North Atlantic and the South Atlantic. The first flight across the Atlantic was made by a United States Navy plane, the *N-C4*, in 1919. This was followed the same year by a nonstop flight by Alcock and Brown. Then came the stirring solo flight of Lindbergh from New York to Paris. Each year saw new records made. In 1933 G. Lemoine of France reached an altitude of 44,819 feet, or a height of considerably over eight miles. In 1933, the round-the-world flight of Post, the 30,000-mile air survey of the Lindberghs, and the mass flight of the Italian planes under General Balbo were the outstanding aviation events. In the fall of 1934 the Englishmen, Scott and Black, won an air race from England to Australia in the astounding time of 70 hours, 59 minutes, and 50 seconds, making the 11,325 miles at an average speed of 159.1 miles an hour. A few days after this event an Italian officer, Lieutenant Azello, made a speed of 440 miles per hour over Lake Garda. These events cause one to wonder what the future of transportation will be.

The Glider Suitable for the Beginner. The art of gliding has made rapid development, and the glider has come back into prominence in the last few years. Prospective airplane pilots get valuable experience in the air by learning to control a glider. There is less danger for a beginner in the glider than in the airplane itself. Under favorable conditions an experienced operator is able to keep his glider in the air for many hours at a time; in a good wind he can soar and gain altitude or he can glide to a lower level at will.

Types of Airplanes. In the history of the airplane we have had two types of machines: the monoplane, in which a single set of planes is used, and the biplane, with two sets of planes. The monoplanes are speedy, but cannot carry as heavy loads as the biplanes. The fuselage, or body of the plane, contains the motor, room for the pilot and operator, and storage for such instruments



Asahel Curtis

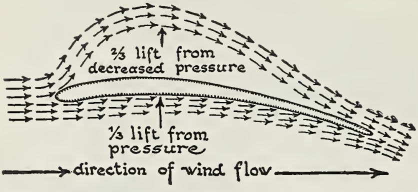
A factory showing trimotor transport planes and navy fighting planes being assembled. What types of planes can you find?

or implements as are necessary. At the rear, the fuselage tapers into a tail to which are attached the rudders, elevators, etc. The hydroplane is an airplane fitted with floats on which it rests on the water. It can rise from and alight on the water.

Demonstration 7. Air Resistance.

How an airplane rises may be tested with a sheet of paper. If the paper is dropped through the air vertically with one edge front, there is practically no resistance and the air pressure is equal on both sides. If it is held horizontally and dropped so that its direction of motion is at right angles to its surface, the under side will compress the air but behind it a partial vacuum will result. When a surface is inclined 45 degrees from the vertical and moved in a horizontal direction with its elevated edge to the front, what do you think will happen? The result will be an upward thrust on the front side which makes the paper zigzag as it falls to the floor, but which, if propelled forward by a motor, would make it rise.

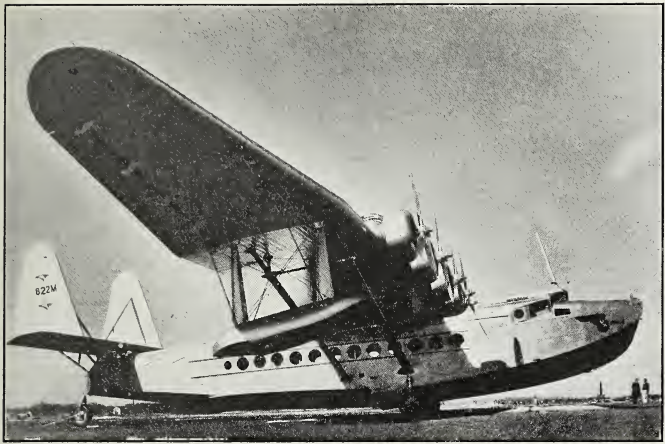
Use of the Wings. The so-called "planes" of the airplanes are really arched or convex as viewed from the top. In ordinary flight these planes are tilted about eight degrees from horizontal, and as the propeller, in front of the wings, pushes back the air, the planes are pulled forward. Because of this motion air strikes against the concave side of the plane with considerable force, and is compressed. At the same time the front of the wing, being elevated above the rear edge, draws away from the air and produces a partial vacuum over a large part of the convex top surface. The result is an upward thrust which is continuous as long as the speed of the airplane is maintained. It is the upward pressure of the moving air that lifts a kite when the strings hold it obliquely to the wind. The difference in application to the airplane wing is that in the case of the kite the wind is moving against the kite, which is held by the string in a more or less stationary position, while in the airplane, the wings are pulled against the air.



Lifting force on an airplane wing. Can a vacuum really lift anything? Explain facts given in the diagram.

Lifting Force, Speed, and Power. The air support depends upon the area of the plane. Double the plane area will give double the supporting force. The air support also depends upon the speed; double the speed will give four times the lifting force. It is thus seen that the lifting power of an airplane increases directly with the surface area of the plane and directly with the square of the speed. In order to double the speed of an airplane the power must be increased eight times.

The Use of the Propeller. The propeller has two blades (sometimes four) whose faces are at an angle to the axis, so that, as they revolve, they will cut the air and push against it just as the electric fan that gives us a cooling breeze pushes on the air. The propellers are placed in front of the plane and pull it along, while in the steamship they are in the rear and push the boat along. For ordinary flight special "elevator" planes are used for rising and for falling. These planes may be tilted at will, causing an upward or downward movement. The "elevator" planes may be placed in front, at the sides, or in the rear.

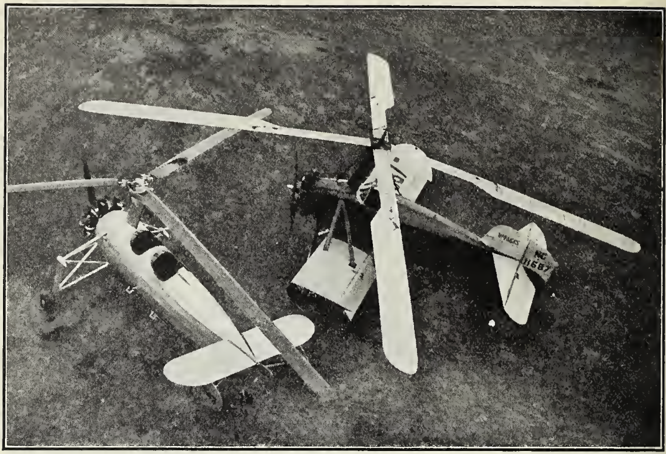


Margaret Bourke-White from Nesmith

The latest passenger planes in the South American service. How many motors are used? Find out what countries are now having airplane service with the United States.

Control of the Airplane. There must be a long runway in order to get speed to lift the plane at the "take-off." Rising and falling are possible by raising or lowering the horizontal elevator planes. A turning movement results from use of a vertical rudder. The action is on the same principle as that of a rudder of a boat in water. By taking a corner at high speed, banking is necessary and this is steadied by use of the ailerons which are placed on each wing. The rudder is operated by moving the pedals on the rudder bar. The elevators and ailerons are operated by the control stick in the hand. By means of many scientific instruments on the instrument board, it is possible for the pilot to watch these and "fly blind."

New Type Planes. Two types of planes have been developed which have four large blades above the plane, arranged to rotate in a horizontal plane. The helicopter has these large blades driven by the engine. The purpose is to lift the plane directly from the ground and to land on a very small area where there is no room for a long run before leaving or after touching the ground. The autogiro looks much like a helicopter but the large blades are not power



Wide World

Two new types of airplanes. The wingless Kellett autogiro is seen at the left; the regular autogiro at the right. What are the advantages of this type of plane? The disadvantages?

driven. As the plane is drawn along by a propeller, the air currents cause the blades to rotate.

Stability of Airplanes. Boats in the water are often subjected to disturbances, such as rocking from side to side and pitching bow and stern. Airplanes experience this same trouble, but to a greater degree. The water tends to keep a boat on even keel to a greater extent than the air holds an airplane. Gravity is pulling the machine down, while the pressure of the air is pushing it up. The pilot's seat is directly over the center of gravity of the airplane. If the center of upward pressure is not at the same vertical line as the center of gravity, a turning will result. The greater the distance between these two centers the greater will be the tendency to upset.

Parachutes. If a man were to jump or fall from an airplane, the constant pull of gravity would increase the speed of his fall thirty-two feet every second that he fell. A drop from a height of a quarter of a mile would give one a speed of three miles a minute when he reached the earth. You can readily see why an unimpeded fall is disastrous. Even before the time of balloons, man had contrived devices with which he could jump from high elevations in comparative safety. These have been developed into our present-day parachutes.

The parachute is a part of the standard airplane equipment of today. When the parachute is opened up, the resistance of the air under the umbrella-like top reduces the descent to a speed of 16 to 20 feet a second. The standard airplane parachute is made from pure untreated silk and, when opened, has an "umbrella" spread of 24 feet. The air held in this umbrella top resists downward motion and checks the speed of falling. It is useless to use a parachute at heights below 150 feet because it takes some seconds for it to open. A person would fall to the ground from a height of 150 feet in about 3 seconds.

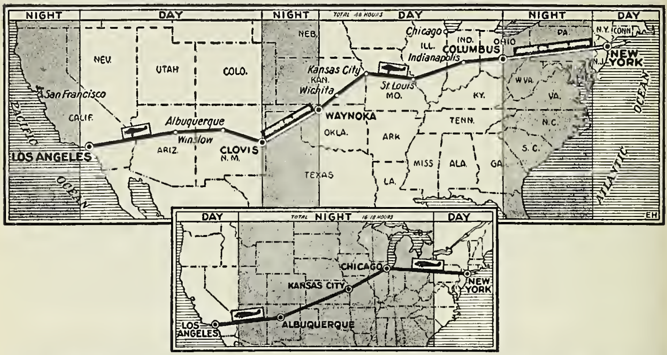
Space Shrinks before Man's Conquest of Distance. When the "Lindbergh Line" from New York to Los Angeles was opened to the public in 1929, much was made of the tremendous advance in air

TERNATIONAL
MARINE

R. I. Nesmith

A Florida airport. To what places do planes regularly travel from this airport?

travel. By combining air travel by day with rail travel at night, the trip across the continent was made in 48 hours. In 1934 regular schedules of all air travel taking 18 hours going west and 16 hours going east were in successful operation. If you can think back to the days when the slow covered wagon traveled these cross-country trails, you must realize how far and fast science has traveled. But do not think it has yet reached its final goal. Progress for the time may be for increasing safety, comfort, and carrying capacity, but there are possibilities for making our map shrink still more by increased speed of the future.


NIGHT
DAY
NIGHT
TOTAL 48 HOURS
DAY
NIGHT
DAY
NEV.
UTAH
COLO.
NEB.
Chicago
IND.
OHIO
ILL.
COLUMBUS
Indianapolis
PA.
N.Y.
CONN.
N.J.
NEW YORK
San Francisco
Kansas City
KAN.
Wichita
St. Louis
MO.
KY.
W. VA.
VA.
CALIF.
Albuquerque
WAYNOKA
TENN.
N.C.
PACIFIC
OCEAN
Winslow
ARIZ.
CLOVIS
N.M.
OKLA.
ARK.
S.C.
LOS ANGELES
MISS.
ALA.
GA.
TEXAS
LA.
ATLANTIC
OCEAN
EH
DAY
TOTAL NIGHT 16 18 HOURS
DAY
CHICAGO
KANSAS CITY
NEW YORK
LOS ANGELES
ALBUQUERQUE

This map shows the advances made in airplane transportation in five years. Read your text and explain the map.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

biplane
four
dirigible
resistance
vacuum
gyroscope

flight
speed
eight
principle
two
land

falling
lifts
monoplane
pressure
lowers
descent

force
ten
upward
box
gliders
downward

The same (1)____ upon which the (2)____ of a kite depends applies equally well to airplanes. The first gliders used were really (3)____ kites. The experiments of the Wright brothers with (4)____ were based on this principle. Two types of airplanes are the (5)____ and (6)____. Increased (7)____ below and a decreased (8)____ above the airplane wings produce an (9)____ thrust which (10)____ and sustains the airplane. Doubling the speed of an airplane gives (11)____ times the lifting force, but to double the speed requires (12)____ times the increase in power. The (13)____ of the air under a parachute checks the (14)____ of (15)____ so that a person may (16)____ safely.

ESSAY TEST

Redney Plans to Become an Air Pilot

Read carefully and critically. List all errors and suggest corrections.

How do I spend my week-ends? If it is pleasant I go to the airport which is near my house. If it is rainy I read magazines and books about aviation in the library. Few discoveries or inventions have led to such rapid progress as aviation. Just think only twenty years ago, the Wright brothers put a gasoline engine in their glider and made the first successful airplane. I like the monoplanes since they are so speedy. I have sat in the pilot's seat and pushed the pedals with my feet just as if I were steering. I pulled the stick toward me to nose up and pushed it to nose down. A wheel on the stick in some planes controls the ailerons. These are little winglets at the outer ends of the big wings. When turning, the ailerons assist in tilting the plane properly or in "banking" as it is called. An airplane can travel eight miles above the earth, but the highest record is nearly twelve miles high.

◆

THE REVIEW SUMMARY

This is a long unit and consequently must have an outline in proportion. Do not neglect the details. Some of the generalizations that may be reached are the following to which you may add others:

1. In order to have permanent roads, they must have surfaces which resist wear.
2. Bridges make use of the laws of levers.
3. The great strength of steel alloy makes it possible to communicate force from a powerful engine to the wheels of an automobile.

4. Cars can be moved by steam, gasoline, and electric motors.
5. Action and reaction are equal and opposite in direction.
6. Balloons and airships make use of the fact that there are gases lighter than air.
7. Heavier-than-air flying machines make much use of the law of action and reaction.
8. Stability in air and in water depends upon keeping the center of gravity lower than the center of buoyancy.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = number of right answers* × $2\frac{1}{2}$.

I. **A good concrete or cement road with a deep foundation:** (1) is the cheapest to build; (2) will wear longer than any other; (3) is satisfactory for all vehicles; (4) cracks badly in hot and in cold weather; (5) is more slippery than any other when wet.

II. **Boats may be propelled by using:** (6) paddle wheels at the sides; (7) a powerful electric fan to blow air against a sail; (8) wings like those on an airplane; (9) a propeller under water at the stern; (10) a gyroscope.

III. **Water transportation is aided by:** (11) deep canals; (12) lighthouses; (13) airport radio beacons; (14) the wireless telegraph; (15) tides.

IV. **A freight locomotive:** (16) may have more than one pair of drive wheels; (17) has drive wheels of larger diameter than the passenger engine; (18) pulls heavier loads than passenger engines; (19) is capable of high speed; (20) makes use of the steam turbine.

V. **The motors in some electric cars and trains are supplied with electricity from:** (21) a trolley wire; (22) a trolley wire or rail under ground, connection being made through a slot; (23) a third rail; (24) a dynamo or battery carried on the train; (25) radio waves.

VI. **The automobile carburetor:** (26) is a vacuum tank holding a reserve supply of gas; (27) pumps gasoline from the tank into the engine; (28) changes liquid gasoline to a vapor; (29) helps produce the gas mixture for the engine; (30) is a device for filtering gasoline.

VII. **The best two gases for lifting a balloon are:** (31) carbon dioxide and hydrogen; (32) illuminating gas and nitrogen; (33) oxygen and hydrogen; (34) helium and hydrogen; (35) helium and argon.

VIII. **The airplane:** (36) rises because the propeller blows air (as an electric fan) against the wings; (37) can travel only against the wind; (38) is pulled through the air by the propeller; (39) has wings so shaped that as they are pulled forward a partial vacuum forms above and greater pressure is produced beneath them; (40) can never rise as high as a balloon can.

PRACTICAL PROBLEMS

1. Suppose you have been promised a trip around the world. Choose two possible routes. Tell the kinds of transportation you might use for various sections of your journey and give the underlying scientific principles for the operation of these. Add notes about any unusual local modes of transportation you might use during some parts of your journey.

2. How has the development of the automobile changed our environment, our customs, our habits; and what effect is it having upon other established modes of transportation?

3. At the beach there is a float of timbers held up by 4 barrels which contain air and are sealed. The top area of the float is 6 feet by 8 feet and when no load is upon it, it stands 8 inches out of the water. If the weight put upon it is evenly distributed, how many 120-pound boys can get on the raft without its sinking below the surface of the water?

4. Can you apply the principle of buoyancy and determine the density of a "gold" bracelet and so find out if it is real gold? How would you conduct the experiment? How can you tell if it is real gold after you have experimented?

5. When you see an ocean freighter entering or leaving a harbor, how can you tell whether it is heavily loaded or lightly loaded?

6. In reading about boats you frequently see these terms: "tonnage," "displacement," "draught," "she is a 10,000-ton vessel," "she displaces 8000 tons of water," and "she draws twenty feet of water." What does each term or expression mean?

7. Two boys are building boats to use on a lake. A is putting a deep lead keel on his boat, but B doesn't do this. What type of boat is A building, and why does he use the heavy lead? What type is B building?

8. If 8 pounds lifting force is desirable in a life preserver you plan to make, how can you calculate the weight or the volume of cork you must use in it?

9. Why is it not necessary to have a life preserver capable of supporting half the weight of a person?

LIBRARY RESEARCH READING

1. Recent trips into the stratosphere
2. Famous air trips
3. Life and work of Robert Fulton
4. Life and work of Henry Ford
5. Life and works of the Wright brothers
6. Progress in streamline transportation
7. Transportation an aid to exploration: to polar regions, to the upper air, to the depth of the ocean
8. History of the bicycle and of pneumatic tires
9. Will air travel at 500 miles an hour ever be practical?
10. Possibilities of a real trip to the moon and back
11. The Lindbergh air survey

SCIENCE FOR LEISURE TIME

1. **The gyroscope.** Get a gyroscopic top. Notice how it resists movement while in action. Read up on its use in cars and boats, and how it acts to help steer an ocean liner.

2. **Toy airplane.** Look up directions for making a model of a simple airplane. Try a number of changes to see if you can improve its flying.

3. **Electric train.** If you have an electric train, try to find out how the engine is constructed. Can you make a diagram showing how the current goes through your electric-train system?

SCIENCE CLUB ACTIVITIES

1. **Flight of airplane model.** If some pupil in the class has a model or toy airplane, let him bring it to a meeting and demonstrate its flight to the club.

2. **Toy yacht race.** If several members have toy yachts they have made in manual arts class or by following directions in Popular Mechanics or Popular Science Monthly, have one session in which the boats are inspected, and have the owners tell the advantages of the lines of their boats. Then have another meeting at a small pond when there is wind for the race.

3. **An assembly program.** Dramatize transportation. Write up the big events as they have occurred historically and present them before the whole school or your entire science group in the form of tableaux.

4. **A debate.** *Resolved:* That in less than 100 years the railroads will be practically replaced by motor busses, trucks, and automobiles.

5. **Survey of local roads.** Make a survey of local roads, kinds of traffic served, types of roads, and condition. Make recommendations.

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Survey Questions

How many methods of communication can you name that are used by people today?

How did men widely separated communicate a thousand or more years ago?

Explain how the telegraph carries your message.

Is sound carried over the telephone wire?

Explain how we can receive the broadcast on our radio.

How is radio broadcasting accomplished?

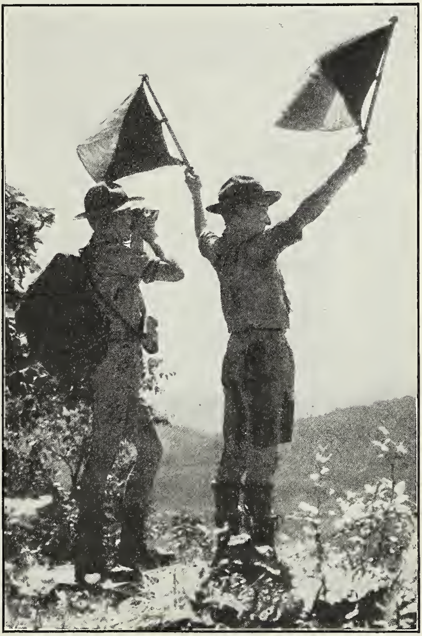
R. B. Holt, R. I. Nesmith and Associates

UNIT X

COMMUNICATION

PREVIEW

From the earliest recorded time people have had means of signaling, the simplest being the flaming torch or bonfire by night or a column of smoke by day. The Romans maintained fires on the coast headlands to guide their triremes of war and commerce. The Greeks developed an elaborate method of torch-signal communication. By using a screen to hide the torches not in use, they could signal all the letters of the Greek alphabet. The American Indians sent daylight messages by covering the fire for a short time with a blanket and quickly uncovering it; thus rings of smoke were sent up which could be seen 20 miles away. The Eskimo finds it more difficult to use fire and does his signaling with his arms. He stands, when possible, on a hill against

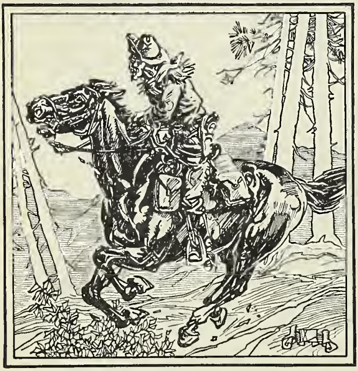


Paul Parker

What type of signaling is this? What are the advantages of such signals over the Indian method?

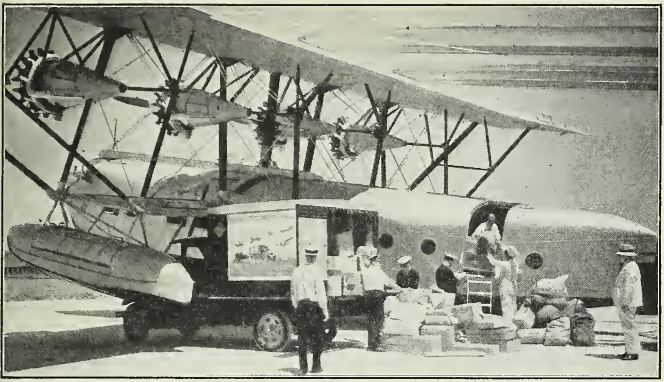
the sky facing his observer. By moving his arms up and down at the sides he gives his message. You perhaps know the scout wigwag signals which are transmitted in a similar way. The Eskimo seems to have been the forerunner of the semaphore, now so common in the railroad train signaling as well as in the navy and army signaling.

Beacon Hill in Boston derived its name from the fact that a beacon light there warned the colonists of the approach of hostile Indians. Lantern light coming from a church belfry gave Paul Revere the information that started him on his famous midnight ride. In 1870 the first plan to use flags and lanterns to transmit messages by a practical code was evolved. This was soon improved so that hundreds of different messages were possible. This led to the wigwag system of the United States army. Our lighthouses with numbered flashes tell the mariner his location, and the airplane beacons flash their messages to the hundreds of planes that now fly from coast to coast. What boy or girl does not know the use of a small mirror to throw a beam of sunlight. Heliograph messages are usually limited to 100 miles, but in exceptional cases have been sent nearly 200 miles. The heliograph is an important instrument in the national forests, being used for communication from one station to another.



Not so long ago mail was rushed across the continent by pony express.

In communicating by signals we may use two of our senses: hearing and seeing. Signaling by sound requires a medium, usually the air, to conduct the waves from their source to the ear. Ear signals are perhaps less important than eye signals, and yet they serve many conditions where eye signals would fail. But all the methods of distance communication, devised by man in thousands of years, are clumsy and inefficient when compared with the telegraph, cable, telephone, and radio, all of which have been



A modern airplane delivering air mail and express packages. Compare this method of communication with that of the pony express shown on the opposite page.

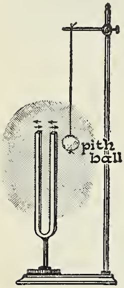
developed within the memory of your parents or grandparents. These new inventions have changed the character of this western country so that all parts of the United States are now within speaking distance of one another. By this contact better understanding and a new spirit of unity have resulted.

Another kind of communication is seen in the delivery of mail. Even the most distant rural population receives and sends written messages at small cost and at frequent intervals of time. To increase the speed of delivery, air service has been established and its network of routes now covers the principal cities of the entire country. Air-mail delivery is now an important part of the postal service.

Perhaps no medium of communication will ever exert a wider influence upon our thoughts and actions than the newspapers and periodicals. It is a far cry from the crude press of Gutenberg, which would print half a dozen single sheets an hour, to a modern power press, which can print and fold over 50,000 32-page papers per hour. Even pictures and drawings can be sent thousands of miles over telegraph and telephone lines or even by wireless so that the modern newspaper not only prints the news, but shows pictures of what has happened a few hours or even minutes after the occurrence. It is an age of wonders that we live in, and as we hear of all these marvels we, too, feel like expressing ourselves in the same words as did Morse's little friend when she was invited to send the first public message over the telegraph. She had Morse send the message: "What hath God wrought?"

PROBLEM I. HOW DO WE USE AIR IN COMMUNICATION?

Sound in relation to our life. Have you ever stopped to think what life would be without sound? No conversation, no music, either vocal or instrumental, and none of the hundreds of interesting events which depend upon sound. We talk and hear through the aid of air, the common medium which carries sound.



Demonstration 1. What Produces Sound?

Materials. Large tuning fork, rubber hammer, ping-pong ball or pith ball fastened to a thread.

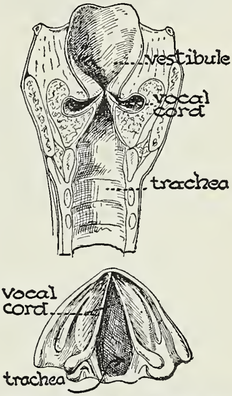
Method and Result. Hold the thread so that the ball will lightly touch the prong of the fork which is still. Strike the fork with the rubber hammer. Bring the ball again lightly in contact with the prong of the fork. When the fork is producing sound, what does it do to the ball?

Explanation. What does the movement of the ball show with reference to the fork?

Practical application. This experiment shows a fundamental fact, that all bodies which give sound are in vibration.

What Is Sound? If we strike the prongs of a tuning fork on a block of wood, we hear the sound. If we strike the prongs again, and lower them into a vessel of water, we see a fine spray of water thrown from the surface. This is because the fork is in rapid motion, actually vibrating several hundred times a second. Just as waves move on the surface of water when we drop a stone into it, becoming wider and wider as they move farther away from their source, so a body that produces sound, as the tuning fork, sends waves off in all directions into the air. These waves fall upon the ear and produce the sensation which we call sound. Vibrations as low as 16 per second are detected as sound, and most people can distinguish sound produced by 20,000 vibrations a second. The range of the piano is 32 to 4000 vibrations per second.

Characteristics of Sound. Sound travels through the air at approximately 1100 feet per second, or about a mile in 5 seconds, but it varies slightly with changes in temperature. It travels faster through glass, metals, wood, earth, or water than it does through the air. If a sound wave strikes a surface, such as a distant cliff, the sound is reflected or is thrown back, and an *echo* is heard. You have all heard echoes in some public hall when the sound which is reflected interferes with the speaker. Sound will not travel through a vacuum, and in general porous substances such as cloth, cotton, or cork are poor conductors. Hence they are used to deaden or insulate rooms to make them sound proof.



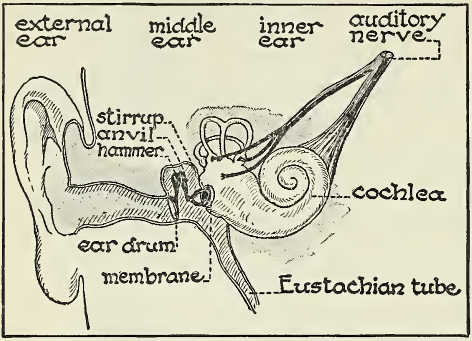
The changes of position and tension of the vocal cords gives us our voice.

Our Voice. Our vocal cords are two thin bands stretched from front to back across the voice box which is situated at the top of the larynx. The tension of the vocal cords, changed by muscular action, regulates the size of opening between them. The tightly drawn cords are set into vibration when air passes through a narrow slit between their inner edges. This vibration causes sound.

Differences in the Pitch of the Voice. A child's voice is shrill or high pitched because its larynx is narrow and the vocal cords are short. When a boy's voice is breaking or changing, there has been a sudden growth of the larynx, and in consequence, a lengthening of the vocal cords.

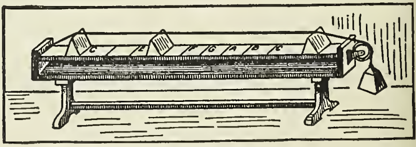
How We Talk. When we speak in a monotone, all of our words are of the same pitch, and yet we can distinguish differences in the sound of different words. This is due to the quality of the sound waves. As these waves pass through the mouth they are changed in quality by movements of the tongue, soft palate, cheeks, jaws, and lips.

How We Hear. Sound and speech would not be of much use to us if we could not hear them. The outer ear, which is simply a structure which helps to collect the sound waves, leads by means of a tube into the middle ear and is separated from it by a delicate membrane, somewhat like that on a drum head. A passageway, called the Eustachian tube, also leads from the mouth to this area, thus equalizing air pressure on the eardrum. In the middle ear are three tiny bones which serve as a bridge to carry the sound waves from this outer membrane to another membrane which guards the inner ear. These sound waves set into vibration the liquid in a chamber in bone surrounding the inner ear, in which the endings of the nerves of hearing are embedded. The nerves in turn carry the sound to the brain. A study of the diagram shows us another part of the inner ear called the semicircular canals, which give us our sense of balance or equilibrium. These delicate structures, set in three different planes, warn us when a bodily adjustment is necessary.



Sound stimuli are gathered by the external ear. The sound waves vibrate the ear drum and then pass into the middle and inner ear and are translated into the sounds we hear in the brain.

Demonstration 2. Find the Relation of Pitch to Length, Thickness, and Tension of Wires.



Materials. A sonometer, wires of different diameters.

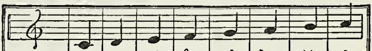
Method and Results. *A*. Pluck a string of the sonometer. Put a bridge under the middle of the string, dividing the string into shorter lengths. Pluck one of these, holding it firm on the bridge. What effect does shortening the string have on its pitch? *B*. Compare the sound of two wires of the same length and tension, but of different diameters. Which gives the higher pitch? *C.* After plucking one string, increase the tension on it and pluck it again. What effect does increasing the tension have on the pitch?

Conclusion. How is the pitch of a sounding wire dependent upon length, thickness, and tension?

Practical application. Why are the wires of a piano of different thicknesses and of different lengths? Why does a piano need to be "tuned"? How is it done?

Music and Noise. Harmony in pitch relations and in the periodic movement of sound waves causes us to think of even and regular vibrations as music, and discordant vibrations as noise. The dropping of a heavy object or slamming of a door is noise, because there is no regularity of vibrations, while the humming of a top when it spins rapidly is musical because the vibrations are regular.

The greater the number of vibrations per second, the higher will be the pitch. When a string vibrates as a whole, it gives its lowest note known as its *fundamental,* but at the same time it may vibrate in short parts, giving subdued tones of higher pitch. These are *overtones.* The vibration of the string as a whole is a *fundamental.* Upon the combination of overtones with a fundamental depends the *quality* of a sound.



name	do	re	mi	fa	sol	la	ti	do
letter	C	D	E	F	G	A	B	C
vibrations per second	258.7	290.3	325.3	345.3	387.6	435	488.3	517.4
standard of physicist	256	288	320	341⅓	384	426⅔	480	512

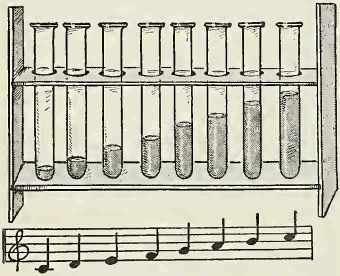
The musical scale beginning with middle C (piano). What would be the vibration rate of each note in the next higher octave of the piano?

The Musical Scale. Our music is built up on a series of sounds having definite ratios of vibration. A study of the diagram shows the staff, with the names of the notes or letters given these notes, and the number of vibrations each makes. This series of tones, which is used for all kinds of musical instruments, is known as the musical scale. Each note in the next higher octave will have twice the vibration rate of that of the corresponding letter in the octave selected in the diagram, and each in the next lower octave will have half the vibration rate of the corresponding tone in the octave noted. The black keys on the keyboard of the piano and organ have intermediate rates of vibration and are used to form other scales. They are the so-called sharps and flats, without which modern music would be impossible.

The Phonograph. The phonograph is a machine invented by Thomas A. Edison for reproducing sounds. It consists of a diaphragm to which a needle is fastened. Any sound produced in front of the mouthpiece or the horn will cause the diaphragm to vibrate, the needle vibrating with it. A wax cylinder or disk is rotated under the vibrating needle and the needle cuts a groove in the wax surface. This groove varies in depth, "hill and dale," or width, "lateral," according to the vibration rate of the diaphragm. The original record is called the *master record* and from it duplicates are made. The records we buy are duplicates of the master record. The reproducing mechanism has a diaphragm capable of very delicate vibrations, connected with a needle which rests on the record. When the record is set in motion, the needle follows the fine wavy groove and is given vibrations which duplicate the vibrations of the original sound waves. These vibrations are communicated to the diaphragm, which causes the sound waves in the air that come to us as reproductions of the original sound. This principle is used in the dictating machine used in many business offices.

Demonstration 3. What Part Does Air Play in Making Music?

A. Add such quantities of water to eight test tubes of small diameter (same size) that when you blow into them in sequence you can produce the scale of eight notes.



B. Cover all the finger holes of a toy tin flute. Blow. Open the holes, one at a time, from the outer end, keeping all those towards the mouth end closed. Keep the hole in the mouthpiece open all the time. Blow into the mouthpiece. Observe the change in the notes produced. The sounding air column is measured from the mouthpiece to the nearest open finger hole. How do you account for the different notes?

C. Produce vibrating air columns in a cornet or a trombone. Observe the difference in pitch. How is it done?

Musical Instruments. Musical sound may be obtained from vibrating strings, vibrating reeds, or vibrating air columns. In the case of strings, the pitch of the sounds depends upon the thickness, length, and amount of tension. In the piano, for example, wires are strung over a sounding board and each key controls a felt-covered hammer which, by striking a blow on the wire, causes the string to vibrate. The pedals control the length of time that the vibration is allowed. In other stringed instruments, such as the violin, mandolin, and banjo, the sound is produced by vibration of the strings and is reinforced by a sounding board directly back of the string.

In wind instruments, the sound is produced in one of three different ways, either by vibrating columns of air, by vibrating reeds, or by lip vibrations. In the pipe organ, the length of the organ pipe determines the length of the vibrating air column and thus determines the pitch of the sound. The longer the column, the lower the pitch. In reed instruments, such as the accordion and harmonica, a current of air causes reeds of different lengths to vibrate. In the saxophone, we have a combination of reed and air columns. The vibrating reed is in the mouthpiece. In the French horn and trombone, not only vibrating lips, but change in the length of the air column plays an important part.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

inner
attention
bubbles
waves
columns
bones
length
lobe
vibration
middle
quality
mouthpiece
drum
fundamental
strength
outer
volume
reeds
depths
straws
tension
chin
overtones
lips
quantity
right
left
pillars
stops
thickness
vibrations
combination

Sound is caused by (1)____ of matter which produce (2)____ in air. The (3)____ ear collects these (4)____ and passes them on to the ear (5)____ which sets in motion tiny (6)____ in the (7)____ ear. These in turn transmit the (8)____ to the (9)____ ear, which is the true organ of hearing. In stringed instruments differences in pitch are produced by differences in (10)____, (11)____, and (12)____ of the strings. Wind instruments produce sound by vibrating (13)____ of air, as in the organ, by vibrating (14)____ in the (15)____ of the instrument as in the saxophone, or by the vibrating (16)____ of the player as in the trombone. The (17)____ of a sound depends upon the (18)____ of overtones with the (19)____ note.

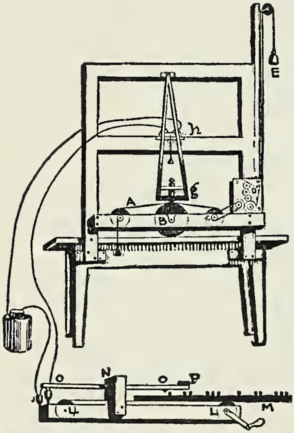
PROBLEM QUESTION

Suppose you are traveling rapidly in an automobile along a road parallel to a railroad track. You meet and pass a rapidly moving train. The bell on the engine is being rung before and after you pass the train.

1. When will you hear the bell at its true pitch?
2. Explain why you will not hear the true pitch all the time.
3. Explain the causes of the differences in pitch that you will hear.

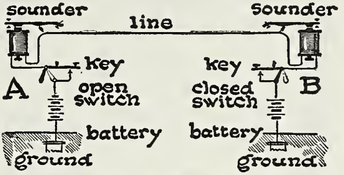
PROBLEM II. HOW IS A TELEGRAM SENT?

The Telegraph. As early as 1831, Joseph Henry produced sounds at a distance by means of electromagnets. The system devised by Samuel F. B. Morse in 1832 and perfected in 1843 is the one, however, which has been generally used, and is known today as the electric telegraph. Today almost every village, no matter how remote, is connected by telegraph with its neighbors. A million messages are sent daily over some of the 225,000 miles of telegraph lines, using all together over 2,000,000 miles of wire in this country. When we compare the conditions of 1844 with those of today, we see what an important place telegraphy holds.



Morse's first telegraph system. When *M* is pushed under *O*, each contact of the projecting points lifts *P* and lowers *J* into the mercury cups, thus closing an electric circuit. An electromagnet *h* acts upon the pendulum which holds a pencil *g* in contact with a strip of paper which is constantly being drawn across the drum *B* by clock work. Each time the circuit is closed, the electromagnet pulls the pendulum to which a soft iron armature is attached and a mark is drawn across the strip of paper.

How the Telegraph Works. The essential materials of a short telegraph line for connecting two houses are plenty of wire, a battery, two keys, and two sounders. The double-wire line well insulated is best, but a one-wire line may be used if connected to a water pipe which, with the ground, makes a return circuit to replace the second wire. The battery should consist of two or more gravity cells[1] joined in series. The key is a device for opening and closing the circuit. The interruption in the flow of the current produces a signal in the sounder at the other end of the line. When no message is being sent, the switch attached to the key is closed. The current always flows through the entire circuit except for the interruption during the sending of the message.

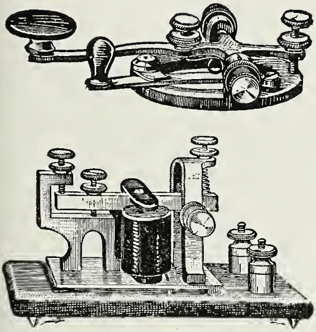


Telegraph circuit. Is the switch in position for *A* or for *B* to send a message?

Demonstration 4. How Does the Electric Telegraph Work?

Materials. Telegraph sounder, key, two gravity cells, wire.

Method. Connect a key and a sounder in circuit with two gravity cells joined in series. Trace the wires through the instrument. Learn the names of the different parts. Open the switch; close it again; open the switch again and close and open the key. Hold it closed for a short and for a long period of time.



Telegraph key and sounder. Name the essential parts.

Note: Dry cells may be substituted for the gravity cells for temporary use. They must not be left with circuit closed.

Results. State the results obtained in each of these trials. Learn to make dots and dashes.

When you have finished with the apparatus, leave it with circuit closed if gravity cells are used. How can you do this?

If dry cells are used, leave with circuit open.

Make a diagram to show the apparatus as used.

Conclusion. What causes the observed results when the switch is closed? When it is open?

How the Telegraph Message Is Received. The essential parts of a sounder are an electromagnet and an armature. When at rest,

[1] Cells which work best when the circuit is kept closed.

	American Morse	International Morse
A	• —	• —
B	— •••	— •••
C	•• •	— • — •
D	— ••	— ••
E	•	•
F	• — •	•• — •
G	— — •	— — •
H	••••	••••
I	••	••
J	— • — •	• — — —
K	— • —	— • —
L	⸺	• — ••
M	— —	— —
N	— •	— •
O	• •	— — —
P	•••••	• — — •
Q	•• — •	— — • —
R	• ••	• — •
S	•••	•••
T	—	—
U	•• —	•• —
V	••• —	••• —
W	• — —	• — —
X	• — ••	— •• —
Y	•• ••	— • — —
Z	••• •	— — ••
1	• — — •	• — — — —
2	•• — ••	•• — — —
3	••• — •	••• — —
4	•••• —	•••• —
5	— — —	•••••
6	••••••	— ••••
7	— — ••	— — •••
8	— ••••	— — — ••
9	— •• —	— — — — •
10	⸻	— — — — —
.	•• — — ••	•• •• ••
?	— •• — •	•• — — ••
,	— • — •	• — • — • —
SOS	••• •• •••	••• — — — •••

Telegrams are sent in American Code and radiograms in International Morse Code. Try to send the original message sent to Morse.

the armature is held close to the electromagnet. If the switch is open, the current stops. There is no longer any magnetism to hold the armature and it is raised by a spring. Upon pressing the key, the current flows, magnetism is produced, the armature is drawn down, and the blow on the yoke results in a loud click. The interval of time between successive clicks is determined by the length of time the key is kept closed. A short interval makes a "dot," and a long interval makes a "dash." Dots and dashes in different combinations stand for the letters of the alphabet. In general, operators learn to read messages by ear. This chart shows the American and the International Morse Code.

In commercial lines where messages are sent long distances, another instrument, the relay,[1] is used. This is more sensitive than the sounder, and will operate on a current which is too weak to operate the sounder. A new type of key is now used. This new key is known technically as the vibroplex. There are two knobs at a convenient level, and the operator squeezes these together. The lever is always vibrating and a slight squeeze closes the circuit.

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[1] Relay (rē-lā′): an electromagnet device by which the opening or closing of one circuit produces a corresponding more powerful opening or closing in another circuit.

The Atlantic Cable. In 1857 a submarine cable was laid from Newfoundland to Ireland, but after working for 18 days, it went out of commission, and it was not until after the close of the Civil War that Cyrus W. Field finally succeeded in laying another cable. At the present time there are over 110,000 miles of ocean cable, forming an underwater network connecting all parts of the world.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

International
closes
battery
Edison
American
dashes
English
ear
electromagnet
opens
armature
Bell
Marconi
dots
switch
Field
lip
flow
key
pipes
interruption
Morse
Wright
cables

The telegraph sounder employs an (1)____ to pull the (2)____ down against the yoke and make a sound. The telegraph operator (3)____ the circuit by means of a (4)____ and spells the word by means of (5)____ and (6)____ which are caused by (7)____ of the current. Operators generally are able to read messages by (8)____. The man who devised a code for sending telegraphic messages was (9)____. There are two codes, the (10)____ and the (11)____. In sending telegrams the (12)____ code is used and in sending radiograms the (13)____ code is used. Messages are sent from the United States to transoceanic countries by means of underwater (14)____. The first successful one was laid by (15)____ after the close of the Civil War.

PROBLEM TEST

Harold and Frank decide to make telegraph instruments. They assemble materials as follows:

Harold gets insulated iron wire, #24, two iron nails for cores, an iron bar for armature, and iron pieces for a yoke.

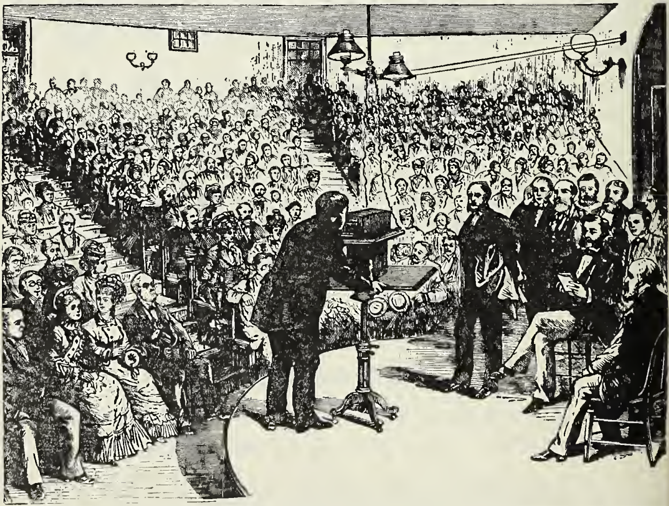
Frank gets insulated copper wire, #24, two iron nails for cores, a copper bar for armature, and copper pieces for a yoke.

1. After the instruments are finished, which do you think will give the better results?
2. Give your reasons.
3. Can you suggest any way to improve the better one of these two?

PROBLEM III. WHAT HAPPENS WHEN WE TALK OVER THE TELEPHONE

To answer this question we must consider first the essential parts of a simple telephone. There is the *transmitter* into which we speak and the *receiver* which reproduces at the other end of the line the speaker's words. Electricity must be supplied through the two instruments and the wires connecting them.

The Beginning of the Telephone. While Alexander Graham Bell was experimenting in sound and speech, he made this statement: "If I could make a current of electricity vary in intensity precisely as the air varies in density during the production of sound, I should be able to transmit speech telegraphically." This Bell



A trial exhibition of Bell's telephone. This scene took place in Lyceum Hall, Salem, Massachusetts in 1876. Compare this with the photograph on page 315. Bell is addressing a group of scientists in Boston, by means of the telephone.

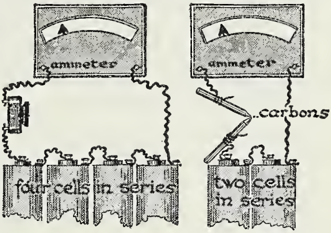
accomplished on June 2, 1875, and on March 10, 1876, the first complete sentence was transmitted.

Demonstration 5. Action of the Telephone Transmitter.

Materials. Telephone transmitter, four dry cells, two electric light carbons, wires, ammeter reading to 10 amperes.

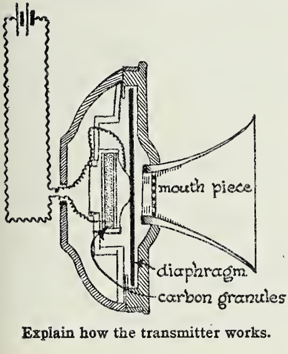
Method and Results. Connect the ammeter, four dry cells connected in series, and transmitter in one circuit. Read the ammeter. Press the diaphragm of the transmitter in; read the ammeter again. Release the diaphragm. Result? Disconnect.

Replace the transmitter with the two carbon pencils and use two instead of four cells; make good contact by winding the bare ends of the connecting wires tightly around the ends of the carbons. The circuit is closed by bringing the two carbons together, and it is broken by separating them. Touch the carbons lightly and read the ammeter. Press the two carbons firmly together, making better contact. What is the result?



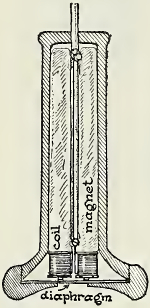
Conclusion. Explain how the fluctuating current is produced in the telephone circuit when one talks into the transmitter. What relation has this fluctuating current to the sound waves we produce in front of the transmitter?

The Transmitter. The transmitter is a little box filled with carbon granules which form a part of an electric circuit, but offer a rather high resistance to the flow of current. If the carbon particles are pressed closer together, resistance is decreased and more current flows. When they separate, less current flows through them. If we were to compress and release the walls of the box alternately, a variable current increasing with pressure and decreasing with absence of pressure would pass through the circuit. One wall of this carbon box is attached to a thin diaphragm just inside the



Explain how the transmitter works.

mouthpiece of the transmitter. Sound waves are vibrations, the air becoming first more, and then less dense in rapid succession. Each compression pushes the diaphragm forward and presses the carbon particles closer together. As the air becomes less dense, the diaphragm springs back to its natural position and the carbon particles separate. In this way, a pulsating current is made to pass through the wire. The number of pulsations and their intensity correspond to the number of vibrations and the intensity of the sound produced in the mouthpiece of the transmitter and these vibrations, as we have just seen, are produced by the vocal cords of the speaker.



Demonstration 6. To Study the Action of a Telephone Receiver.

Materials. Telephone receiver, a dry cell, wire, a coarse file, a fine file.

Method and Results. Connect one pole of the cell to one binding post of the receiver and the other to one end of a coarse file. Join one end of a wire to the other binding post of the receiver, leaving the other end free. Hold the receiver to the ear.

Run the free end of wire along the smooth surface of the file near the end. Result?

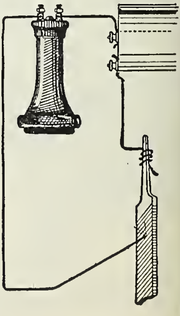
Run the free end of the wire along the rough surface of the file. Result?

What different effect is noticed if a fine file is used? If the speed of drawing the wire along the file is increased?

Unscrew the cap on the end of the receiver to see the inside structure of the receiver. Bear in mind that when the wire is drawn over the file ridges, electrical contact is made only when the wire is touching a ridge.

Conclusion. Explain the result detected by the ear.

Make a diagram to show the working parts of the receiver. Is the receiver an electromagnetic device?



How the Receiver Gives Us the Sound Waves. Suppose the electric circuit in which the transmitter is connected also includes a telephone receiver at a distance. What will happen when the pulsating current comes to it? If you should unscrew the cap at the end of the receiver, you would find a thin, soft-iron diaphragm held in place by a permanent magnet. Remove the diaphragm and you will find two small coils of wire around the end of the magnet. These coils form the part of the electric circuit which carries the pulsating electric current. Every time the current is increased, the magnetism is made stronger and the diaphragm is drawn closer to it. Every time the current decreases, the magnetism becomes weaker and the diaphragm springs back. This completes the vibration. Vibrations are made as often as the pulsations of the electric current occur, and these, you recall, correspond to the number of vibrations of the sound in the transmitter mouthpiece. The vibrating diaphragm of the receiver sets up sound waves in the air which are duplicates of those given to the transmitter. Thus it is that speech is reproduced at the other end of a telephone line with no sound waves, but only pulsations of electric current being transmitted over the wires. In order to strengthen the loudness and decrease the loss of electricity along the line, an induction coil is used in the telephone instrument to "step-up" the voltage.

Use of the Induction Coil. There is less loss from the wires if electricity travels at high voltage, so the current which passes through your transmitter is stepped-up to a higher voltage by means of a transformer before going out to the main line. The local current flows through the primary coil as soon as you take down the receiver. As you talk before the transmitter, your vocal cords vibrate, thus causing variations in the strength of current in the primary coil. These fluctuations[1] in strength induce corresponding fluctuations in the secondary coil. But the voltage is higher in the secondary because of the greater number of turns of wire, and this "stepping-up" enables us to hear at the other end of the line.

Highways of Speech. Have you seen the large lead-covered cable stretched from hundreds of poles? This may contain hundreds of pairs of wires separated by thin paper wound around each wire. In thickly settled districts these cables are run through underground conduits. Each pair of wires is a private way for just those parties whose phones are connected. Trunk lines connect large cities which are divided into sections or "centrals" — each with a special name, such as "Spring," "Walker," or "Morningside." From each of these centers there are wires to all the telephones in that section. When you telephone someone in your own section, connection is made direct at your central office. But if you call someone in another section, connection must be made between your central and the central of the other section through a trunkline highway, and then this highway is joined to the person's telephone in this section. New York City has over one hundred of these sections.

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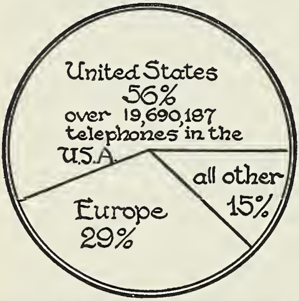
[1] Fluctuation (flŭk′tū̇-ā′shŭn): varying or changing in strength of current.

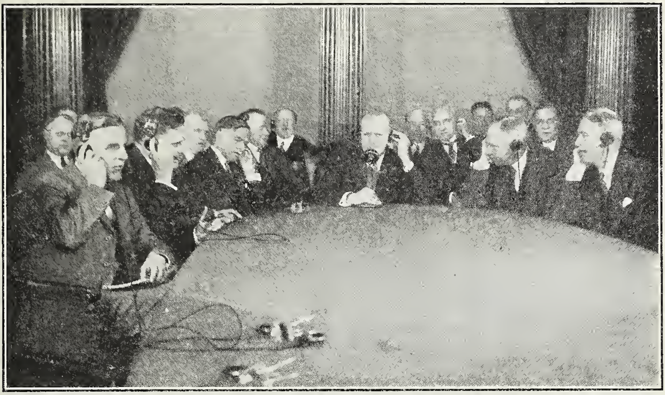
There are three telephone highways in the United States, so that anyone in the East or Middle West can talk with anyone on the Pacific Coast. He will be joined to his party at one of the three terminals of these trunk lines. These transcontinental lines have their western terminals at Los Angeles, San Francisco, and Seattle.

Dial Telephones. Automatic connection with your party is possible in many cities by use of the dial phone. When you lift the receiver to your ear in using the dial phone, you hear a low, buzzing sound. As you move the dial, currents are sent to a number of different relays in your own central circuit and in the central circuit of the party you are calling. The selecting and switching frames which automatically perform this wonderful work are too complicated for us to attempt to explain. The communication is carried on by use of the same principles as in any other system.



Where are the world's telephones used?

It is estimated that the people of the United States make 27,000,000 telephone calls a day or about 10,000,000,000 a year. For these nearly 20,000,000 telephones are used, many more than for all the rest of the world put together. This means about 87,000,000 miles of telephone wires, and an investment by the telephone companies of around $7,000,000,000.



Wide World

This picture shows the officials of the American Telephone and Telegraph Company listening into the first transatlantic telephone call. Do you know on what date this was made?

Long-Distance Telephoning. The greater the distance a current travels, the weaker it becomes. When the current in the telephone wires is very weak the sounds are distorted.[1] Various devices have been tried to make it possible to increase the distance at which conversation can be carried on successfully. The first long-distance lines made use of the Pupin "loading coils" which, while they did not add energy to the line, did make it possible to deliver a greater part of the energy to its destination than had formerly been possible.

Today a vacuum-tube repeating amplifier[2] is used on transcontinental circuits. This amplifier is similar to the radio detector patented in 1908 by DeForest. It acts as an electric valve, so that when the weak current from a distant station comes in, it will allow a stronger local current to strengthen it and passes it on to the telephone lines. This is a wonderful invention because the current which is sent on is an exact reproduction of the feeble current received, but increased to many times its strength.

International Radiophone Communication. The year 1927 marked the opening of commercial radio telephonic communication across the Atlantic Ocean, between New York and London. This service has since been extended to practically all European countries, to Mexico, to South America, and even to far-off Australia. This wonderful achievement is a culmination of scientific experiments covering a score of years and is the result of joining the forces of wired telephone lines and radio. Long radio waves are most frequently used.

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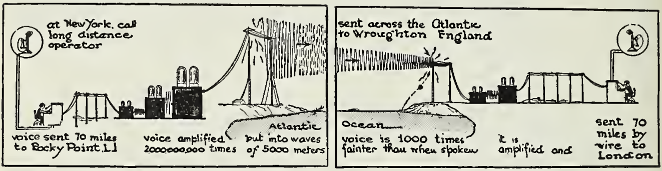
[1] Distort (dĭs-tôrt′): to deform or twist out of shape.

[2] Amplifier (ăm′plĭ-fī′ẽr): a device to increase the strength of electric impulses.


at New York, call long distance operator
voice sent 70 miles to Rocky Point L.I
voice amplified 2,000,000,000 times
Atlantic
put into waves of 5000 meters
sent across the Atlantic to Wroughton England
Ocean
voice is 1000 times fainter than when spoken
it is amplified and
sent 70 miles by wire to London

How a telephone message is carried from New York to London. Compare the distance it travels by electric pulsations in wires and by radio waves through space.

There are methods of modifying the waves so that they will be unintelligible to anyone except at the station equipped with the right device for changing the waves back to normal. In this way telephone conversations between parties in Europe and the United States are kept private.

Multiplex Systems. The Atlantic-Pacific trunk lines consist of a group of four wires so arranged that three separate conversations can be carried on at the same time. A new development which makes it possible to carry telephone and telegraph messages over the same wires employs what is known as "carrier" waves. The same wire can carry several electric currents which vary in frequency. Five different telephone conversations or twenty-four simultaneous telegraph messages can be sent by this system over a single pair of wires. Work is now being done on a cable which will span the Atlantic Ocean and which will carry telephonic messages in addition to cablegrams.

The Carrier Telephone Cable to Havana. In 1931 the longest deep-sea telephone cable in the world was opened, connecting Key West to Havana. The cable has a central conductor and insulated from it a concentric metal tape for the return circuit. By using a system of carrier waves of different frequency bands, three telephone conversations and several telegraph messages may pass over the same wire at the same time without interfering with each other. For each telephone conversation two channels of carrier waves are used to avoid interference. The message from Key West goes on one carrier frequency, but the return message is on a different carrier frequency.

The Simplex Printer. Sending messages by key is slower than a person can write, but a method called the simplex printing telegraph has been developed which is faster than you can talk over the phone. The printer has a keyboard that resembles a large typewriter. Six girls may type as fast as possible messages which are all passed over one wire and are automatically printed on long strips of paper in a distant city.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

frequencies
position
magnet
pulsations
sound
vibrate
carrier
more
transmitter
vibration
wire
carbon
strength
current
fluctuation
pressure
coils
resistance
efficiency
weakness
receiver
carrier
diaphragm
less

When a person speaks into the (1)____ of the telephone, the (2)____ granules crowd together and spread apart alternately with the (3)____ of the (4)____. When crowded together, the (5)____ is decreased and (6)____ current flows. When the (7)____ comes into the telephone receiver, it passes around the (8)____ at the end of the (9)____ and by changing the (10)____ of the magnetic field, causes the (11)____ to (12)____. This sets up (13)____ waves in the air. The (14)____ waves sent into the mouthpiece are not transmitted over the wires, but cause (15)____ of current which are translated again into (16)____ waves in the telephone (17)____. More than one message can be sent over the same wire by using (18)____ waves of different (19)____. This method increases the (20)____ of each pair of wires.

PROBLEM TEST

Explain why in telephoning it is not necessary for sound to travel over the wire from one telephone to the other.

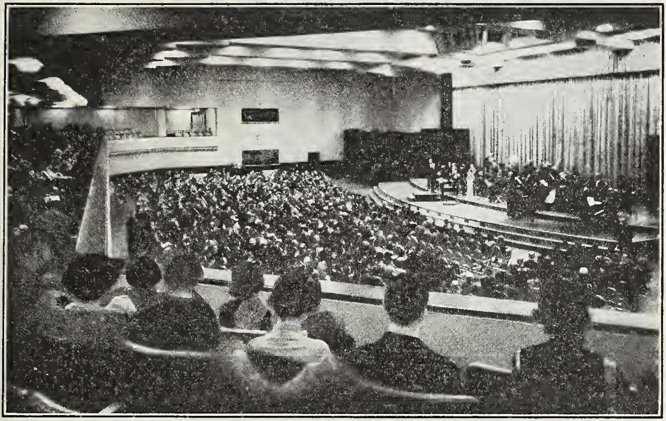
PROBLEM IV. HOW ARE RADIO PROGRAMS SENT OUT AND RECEIVED?

Radiation through Space. Radiations of many kinds are passing through space all around us all the time. We can detect heat radiations when they are strong and we readily recognize radiations of light. Both heat and light radiations may be absorbed by matter. The absorbed heat increases the molecular vibrations of the molecules in matter. This produces a rise in temperature as you can observe if you hold your hand directly in sunlight. Man sends out light waves from a powerful searchlight that can be received by the human eye at a great distance away. Electrical waves differ from light and heat radiations only in their *wave length* and vibration rate, which is called *frequency.* The human eye is not sensitive to them. When a good conducting material extends high into the air and is connected to the earth, electrical waves that are passing are caught by it and surging waves of electrons back and forth through the conductor result. This movement of electrons is in reality an alternate current of electricity. An antenna (aerial) is used to pick up these rising and falling electrical waves from space.

Radio Waves. All radiant energy, whether it be heat, light, or electricity, travels through space at the tremendous speed of light, 300,000,000 meters (186,000 miles) per second. This velocity is the product of the wave length and frequency. Frequency means the number of vibrations per second. Thus a wave of 100 meters must have a frequency of 3,000,000, and a wave of 3000 meters will have a frequency of 100,000. These figures are so large that a new frequency unit, called the *kilocycle,* has been adopted. "Kilo" means a thousand, and "cycle" means one complete alternation. Kilocycle then indicates the number of thousands of times that the wave alternates in the antenna circuit in one second.

What Is a Broadcasting Station and How Is It Equipped? A broadcasting station consists of two distinct departments, a *studio,* where the speakers and artists present their programs, and a *transmitting station,* where the radio-transmitting equipment is operated. A powerful sending station close by interferes with the reception of distant stations. Consequently, locating the transmitting station miles away from the city studio favors better reception by the city people.

In a well-equipped studio the walls are covered with sound absorbing materials, and thick rugs are on the floor. Every precaution is taken to prevent echo. When a chain of stations broadcast the same program, the program is sent by telephone wire to every station in the chain. The program may thus travel hundreds or perhaps thousands of miles over the telephone wire before it is sent out by the local radio station.

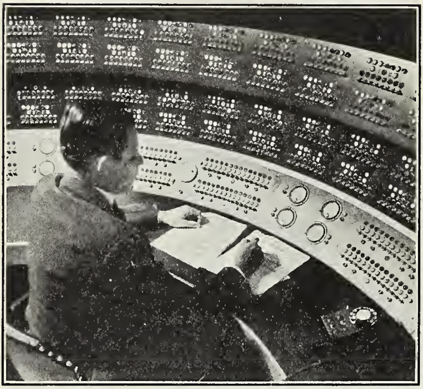


National Broadcasting Company

An auditorium broadcasting studio. Many microphones are carefully located on the stage and these are connected to the transmittting station.

The Transmitting Station. Inside the transmitting station there are generators which produce the electric current, pumps which supply water to cool the huge transmitter tubes, and a number of transmitting instruments. Here the pulsating electric current from the microphone is received and changed into radio waves. These waves are capable, after passing from an antenna to a receiving set, of being converted back into sound waves.

Sending Out Radio Waves. In a broadcasting station a device called an *oscillator* produces an alternating current of high frequency. Each station is assigned a frequency which the Government requires it to use. The high frequency wave is the *carrier wave* which produces the steady hum you hear from a given station when it is tuned in and nothing is being broadcast. In the studio, the sounds to be broadcasted are produced in front of a microphone which is like a very sensitive telephone transmitter in principle. The fluctuating sound current produced here is strengthened by an *amplifier*. The carrier wave and amplified fluctuating sound currents are then brought together in a device called the *modulator*. The pulsations of the sound current are much slower than the alternations of the carrier wave. The result of the action of the pulsating sound current upon the carrier wave is the *modulated wave*. This modulated wave carries with it the characteristics of the sound to the antenna of the broadcasting station. Here it sets up radiations which carry all these characteristics of sound across space.



National Broadcasting Company

The main control desk of a large broadcasting station. This keyboard controls 85 different stations on a coast to coast network. The lights represent the different stations.

Receiving Radio Waves. When an antenna is connected to the ground by means of a conducting wire, it will receive the radio waves that travel through space. The wire connecting the antenna and the ground will have electric currents surging up and down through it which carry the characteristics of the sound from the broadcasting station. The receiving apparatus must have a tuning device so only one station will be heard at a time. It must have an amplifier to increase the volume and a detector which modifies the current so that it will act upon a loud speaker.

Tuning. If we understand how a body is set into vibration when it receives waves sent through matter from another vibrating body, it may help us to understand how radio waves may set up electrical vibrations in wires of proper length and capacity.

ALLOTMENT OF RADIO CHANNELS[1]

FREQUENCY KILOCYCLES		WAVE LENGTH METERS
10	Fixed service, government and coastal, ship telegraph, public radio telegraph, state police (190)	30,000
200	General communication, government, aircraft (224), radio beacon (297–299)	1,500
300	Government, general communication, aircraft, radio beacon, direction finding (375)	1,000
400	Coastal telegraph, ship telegraph (468), aircraft (over seas 414,457)	750
500	International calling and distress and ship and aircraft over seas	600
550	Broadcasting	527.2
1,500	General communication, experimental (1530, 1550, 1570)	200
1,600	Experimental, police, air navigation, motion picture station	187.5
1,700	Amateur, police (1706, 1712)	176.5
2,000	General communication, police, experimental, visual broadcasting (2008–2096, 2752–2848), fixed service, government, aviation, special emergency (2724–2728)	150
3,000	Itinerant aircraft (3105), listening "watch" at licensed air port stations (3105) required between sunrise and sunset, aircraft and stations, amateur (3500–4000), coastal radio phone, ship service, general communication, government	100
6,000	News items for the press, amateur, experimental, relay broadcasting, fixed service, government, transatlantic telephone	50
20,000	Experimental, visual broadcasting, amateur, general communication, fixed service, government	15
100,000	Experimental, visual broadcasting	3
400,000	Amateur (400,000–401,000)	0.75

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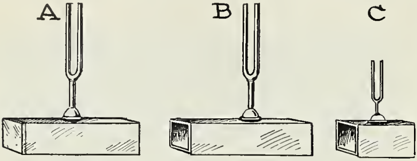
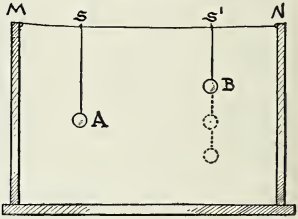
[1] For more detailed assignments see bulletin "Federal Radio Commission — Rules and Regulations, 1934."

Demonstration 7. Tuning Analogies

(*a*) *With Tuning Forks.* Demonstrate sympathetic vibrations with two tuning forks of 256 vibrations per second, each mounted on a sounding box. Set one fork into vibration when it is near the second fork. Stop its vibrations and listen to learn if the second fork has picked up the sound and is vibrating. If another fork of different vibration rate is near by, you can find by test whether or not it is set into vibration.

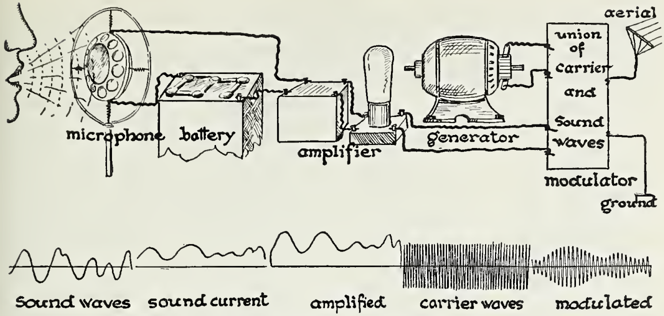


(*b*) *With Pendulums.* Fasten a wire two feet long between supports *M* and *N*. Support a lead ball *A* on a thread 12″ below *S* where it is held firmly to the wire. Suspend a second lead ball *B* from *S*′ on a thread whose length is 20″. Set ball *A* into motion. If *B* does not take up the motion and swing with it, change the length of the thread. Try 8″, 12″, and 15″. Tuning consists in adjusting the length of pendulum *B* so that it will be set into vibration when *A* vibrates. From the various tests find out where it responds best to the vibrations of *A*.

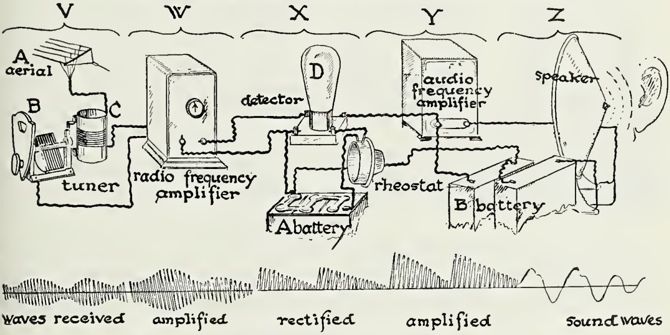


We have seen that one tuning fork will set another into vibration only when it has the same vibration rate and that a swinging pendulum sets another into vibration only when the other is of the same length. When one body imparts motion to the other it is in tune with it. There is a similar action in radio tuning, although it is not a mechanical vibrating action. The antenna-ground circuit may be adjusted to make it receive a given frequency. This adjustment is called *tuning*.

Tuning Devices. The two chief tuning devices in the radio receiving set are coils of wire and variable condensers. You remember that by varying the length of a coil or changing its position with relation to another coil, the magnetic induction is varied. This also causes the voltage to vary. These changes cause what is known as a change in inductance. We increase the inductance to


aerial
union of carrier and sound waves
microphone
battery
amplifier
generator
modulator
ground
sound waves
sound current
amplified
carrier waves
modulated

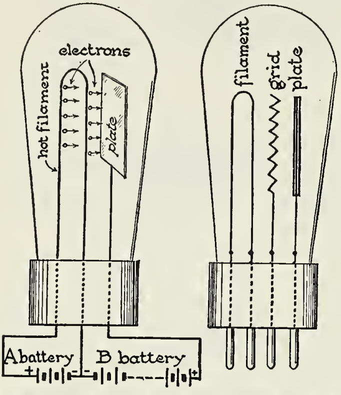
The transmitting equipment changing sound to radio waves.


V
W
X
Y
Z
A
aerial
B
C
tuner
radio frequency amplifier
D
detector
A battery
rheostat
audio frequency amplifier
B battery
speaker
waves received
amplified
rectified
amplified
sound waves

The receiving equipment changing radio waves back into sound.

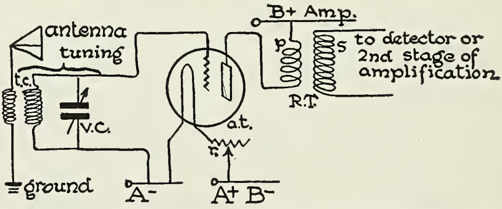
receive low frequencies (long waves); we decrease the inductance to receive high frequencies (short waves). The condenser consists of metal plates separated by some good insulating material. By having one set of movable plates intermeshing with other non-movable plates, the relative positions of the two may be changed so that the capacity for storing electricity is changed. Thus in tuning, you make adjustments so that the electrical waves of a particular length will set up action in your receiving set.

The Radio Vacuum Tube. Long before scientists knew anything about electrons and protons, Thomas Edison made a discovery which, though interesting, was not considered of any importance at that time. He introduced a third wire into the bulb of an incandescant lamp and joined it to the positive pole of a battery whose negative pole was joined to the negative of another battery that supplied the filament with current. When the filament was hot, Edison found that a current of electricity would flow across the gap and through this wire, though there was not a complete metallic circuit. This is known as the *Edison effect* and it is now explained by the fact that the *hot filament* gives off electrons which are attracted by the positively charged wire. Electrons ran across the space in the tube to the wire and in this way they completed the circuit. A little later Fleming, an Englishman, substituted a *plate* for the third wire, making a device called the *Fleming valve.*


electrons
hot filament
plate
filament
grid
plate
A battery
B battery
+
-
+

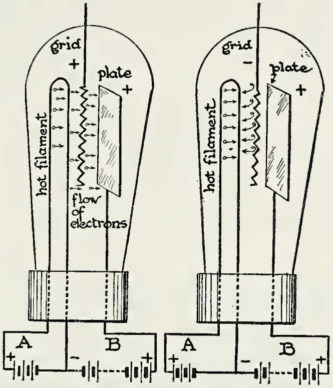
The Fleming valve is shown at the left and the DeForest radio tube at the right. What is the purpose of the grid shown in the tube at the right?

Our radios of today depend upon an addition to this tube made by Lee DeForest. He added a third element called the *grid.* The grid is placed between the filament and the plate, and these three elements — filament, grid, and plate — are found in all our modern three-element tubes.


B+ Amp.
antenna
tuning
t.c.
V.C.
p
s
to detector or
2nd stage of
amplification
R.T.
a.t.
r
ground
A-
A+ B-

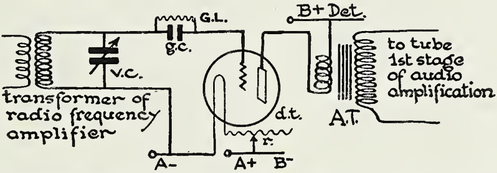
Tuning and radio-frequency amplification. What is the purpose of the parts illustrated?

Radio-Frequency Amplifier. The incoming signals or electrical oscillations picked up by the antenna are so exceedingly weak that they must be amplified. This is usually done by means of an amplifying tube and a "step-up" transformer. The incoming oscillations, after tuning, are carried directly to the grid. The plate circuit goes through the amplifying transformer, which has two coils of wire: the primary with few turns and the secondary, many turns. This makes the voltage in the secondary coil greater than the original voltage in the primary coil. The strengthened oscillations are then delivered to the detector tube unless a second stage of radio-frequency amplification is used. One tube and one transformer make up one stage of amplification. A receiving set may have one, two, or more stages of radio-frequency amplification.


grid
+
plate
+
hot filament
flow of electrons
A
B
+
-
+
grid
-
plate
+
hot filament
A
B
+
-
+

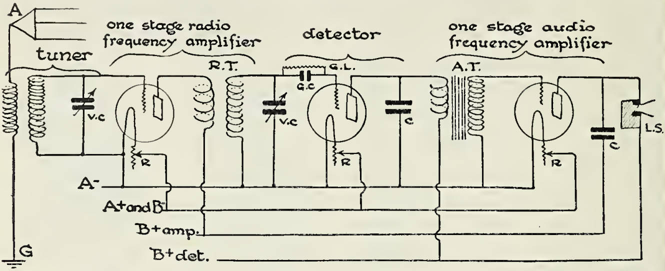
Can you tell why the grid aids the flow of electrons in the plate circuit sometimes, while at other times it checks the flow of electrons?

Action in the Detector Tube. The purpose of the detector tube is to rectify the alternate current; that is, to allow the current to flow only in one direction, and it also removes the high-frequency or carrier wave. The alternate current, brought in from the antenna and amplified, consists of a positive and a negative phase. During the negative phase, the grid is negative, and electrons from the hot filament are driven back into the filament. During the positive phase of the alternate current the grid is positive and electrons are aided in making their way from the filament to the plate. This allows a current from the "B" battery to flow through the loud speaker or to the audio-frequency amplifier.


G.L.
g.c.
B+ Det.
V.C.
transformer of radio frequency amplifier
d.t.
r.
A.T.
to tube 1st stage of audio amplification
A-
A+ B-

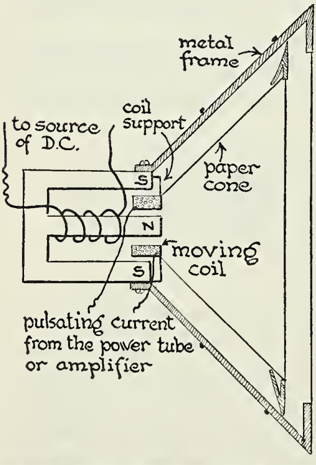
The detector is between the two types of amplifiers. Why are two types of amplifiers used?

Audio-Frequency Amplification. The current which comes from the detector tube is a pulsating direct current similar to the current which passes over a telephone wire and when amplified may go to a phone receiver or loud speaker.


A
tuner
one stage radio frequency amplifier
R.T.
V.C
R
detector
G.L.
G.C
V.C
C
R
one stage audio frequency amplifier
A.T.
R
C
L.S.
A-
A+and B-
B+amp.
B+det.
G

A simple 3-tube set. After studying the text explain the difference in the electrical impulses in the two transformers.

The Dynamic Loud Speaker. The pulsating current coming from the detector tube or from the audio-frequency amplifier may be transformed into sound by the same principle employed in the telephone receiver. The varying current creates varying magnetic force which causes a disk to vibrate and set up sound waves in air. This is actually the case when headphones are used. There are several types of loud speakers in which the change from electrical pulsations to mechanical vibrations are brought about in slightly different ways. In the dynamic loud speaker a paper cone instead of a metal diaphragm may be set into vibration. In the dynamic speaker one pole, say the north, is centered inside an outside ring which is the south pole. The magnetic field across the space between the poles is maintained at

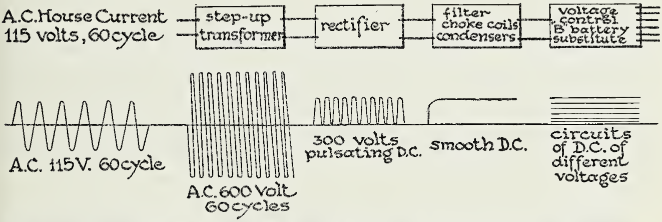

metal frame
coil support
to source of D.C.
paper cone
S
N
moving coil
S
pulsating current from the power tube or amplifier

The dynamic loud speaker. Why is direct current used for the field magnet?

a uniform strength by means of a direct current. A small coil of wire surrounds the end of the north pole, being suspended in the gap between the north and south poles. The coil is free to vibrate. The pulsating current bearing the characteristics of the sound are brought into this coil and cause it to vibrate. A cone is fastened to this coil, and any vibration that may occur in the coil is transmitted to the cone. The vibrating cone sets up equivalent vibrations in the air, which we receive as sound.

Use of the Alternate Current. In the early days of radio, all receiving sets used the "*A*" and "*B*" batteries. Today they are still used in automobile radio sets and in homes where electricity for lighting is not available. It is possible to change the voltage of the alternating electric-light current through the use of transformers. The current is changed to the equivalent of direct current.

Short-Wave Receivers. Ordinary broadcasting covers a band of wave lengths of 200 to 527 meters, or 1500 to 550 kilocycles' frequency. Most of the short-wave bands lie within 15 and 200 meters, or 20,000 to 1500 kilocycles. The radio built to cover a range of 200 to 600 meters cannot tune in the waves which are shorter than 200. The short-wave range is so much greater than the broadcasting band that no one instrument can cover the whole range except by the use of extra condensers or tuning coils of varying capacity. There are converters and adapters which can be connected to the long-wave receiver so that it will bring in the short waves. The converter changes the short waves to long waves that can be received by the regular set. The adapter is a short-wave tuning unit that can be substituted for the first stage of radio


A.C. House Current
115 volts, 60 cycle
step-up transformer
rectifier
filter choke coils condensers
voltage control "B" battery substitute
A.C. 115V. 60 cycle
A.C. 600 Volt 60 cycles
300 volts pulsating D.C.
smooth D.C.
circuits of D.C. of different voltages

When the alternate house current is substituted for the direct battery current, whether for short wave or ordinary broadcast reception, it must undergo many changes as shown above.

frequency in the long-wave receiver. If the short-wave receiver covers a wide range, there will be an extra knob on the panel by which one coil or another may be brought into circuit, and then tuning within the range of that coil is done as usual.

Uses of Short-Wave Radio. The short waves are used for police messages, news for the press, transatlantic telephone, and government service. Some regular broadcasting is sent out in different countries in short waves. The advantage of short waves is that in general they travel longer distances for a given amount of power. They are freer from static, and they provide a wider field without interference from other stations.

Other Uses of Radio. Long before our use of radio in our homes, Guglielmo Marconi had developed and made practical commercial use of radio waves in a system of "wireless" or radio telegraphy. This is in use today all over the world and finds a special field in sending messages to and from vessels at sea. The international code of dots and dashes is used.

Radio beacons and radio stations serve to direct ocean and air travel. Two parallel directional radio beams are sent out from the stations, one of which continually keeps sending a certain signal, and the other one sends a different signal. An air pilot steers between the two. If he swerves from his course to one side, the signal becomes stronger and he turns back. But the signal from the other beam will tell him if he goes too far in that direction.

Trial has shown that ships and torpedoes can be directed by radio operators at distant points. Bombs can be discharged from the plane at any desired time. Tractors pulling gang plows have been operated by a radio stationed at one end of a field.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. A word may be used more than once.

aircraft
aerials
alternating
amplifier
amplify
battery
broadcasting
beacons
condenser
cells
carrier
disk
detector
frequency
grid
modulated
plates
rectified
radiations
telegraphy
telephone
transformer
wires
microphone

The instrument used in radio (1)____ which takes the place of a transmitter in a (2)____ system is called a (3)____. Radio waves differ from light and heat (4)____ in wave length and (5)____. The electrical signals caught by the antenna produce (6)____ currents in the connecting (7)____. They may be passed through a tube and (8)____ having an air core to (9)____ them. The current is rectified in the (10)____ tube, which also sifts out the (11)____ wave. Code similar to that used in wire (12)____ is sent by radio. Radio (13)____ can be used to guide both ships and (14)____.

PROBLEM QUESTION

I. Suppose you are listening over the radio to an orchestra. There are many things that make this possible. Tell how and where:

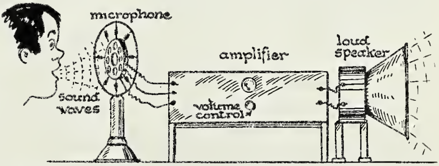
1. Mechanical vibrations are of assistance.
2. Electrons help.
3. Radiations are used.

II. To what extent are the new methods of communication likely to replace the old?

1. Is it likely that the radio-telegraph (wireless) will some day do away with most of the wire-telegraph business? Explain.
2. Is it likely that the radiophone will some day replace most of the individual house telephones now in use? Explain.
3. Is it likely that ocean cables will be supplanted by the transoceanic radio telegraph and radiophone? Explain.

PROBLEM V. HOW ARE SOUNDS AND PICTURES PRODUCED AND RECORDED?

Public-Address System. Some of the devices developed for radio broadcasting and reception have been found useful where no waves are sent out through space from one antenna to another. In many large halls a speaker cannot be heard in the rear unless his voice is strengthened. By using the microphone, amplifiers, and loud-speakers,



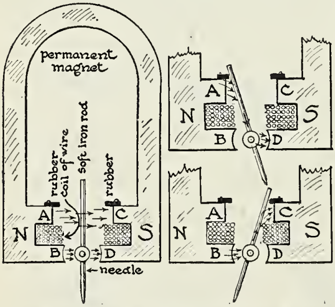
The essential equipment for a public address system. Name two devices you would expect to find inside the amplifier box.

all joined by wire connections, a speaker can address many thousands. Not only can he be heard throughout the largest auditorium, but additional loud-speakers can be connected to carry his voice to as large an area out of doors as may be desired.

No carrier wave is used and so no tuning equipment is needed and the amplifier will be of the audio type. The microphone delivers a pulsating voice current to the amplifier and power tubes. A five-tube amplifier will give good volume for a fair-sized auditorium. A simple-type amplifier needs only a volume-control knob.

When more than one microphone is to be used and when a phonograph is to deliver music in place of one of the microphones, it is necessary to add a device called a "mixer." This consists of a separate transformer for each microphone inlet. These transformers must be carefully balanced so that they will all carry the voice uniformly. If three microphones are joined to the amplifier, even though they are far apart, three people can speak and be heard from the same loud-speakers. The three, of course, must not all speak at once.

The Phonograph Pickup. The amplifier makes it possible to take sound from phonograph records and increase its volume so that it will fill a large auditorium. This new device is known as the phonograph pickup. You are familiar with the ordinary phonograph arm which has a needle that runs in a groove on the record. This needle carries vibrations to a disk which produces sound. But in the electric phonograph pickup, the needle serves quite a different purpose. There is a small but powerful permanent U-shaped magnet which has a coil of wire held in a recess in the poles facing each other. The needle is pivoted between these poles so it can move back and forth under control of the groove in which it runs. In doing so it moves a small soft-iron

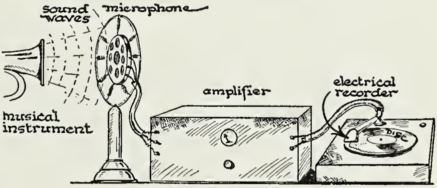


Can you explain how the phonograph pickup works?

rod above it back and forth in a manner to distort the lines of magnetic force and thus generate electric currents in the coil of wire.

If you study the diagrams, you will see that when the rod is vertical the lines of force pass from A to C and B to D. When the iron rod is near A, the lines of force pass along the rod from A to D. When the iron is near C, the lines of force pass from B to C. These changes in the lines of force produce an induced alternate current in the coil of wire. The coil is connected to the primary coil of an audio transformer in the amplifier. The pulsations of electric current are determined by the vibrations of the needle, which reproduce those of the original sounds. These pulsations, after proper amplification and rectifying, are turned into the loud-speaker, where sounds, the duplicate of the original sounds used in making the record, are reproduced.

Making a Disk Record. Phonograph records were originally made by collecting the sound in horns at whose apex was a thin diaphragm whose vibrations were transferred through a needle to a wax disk. The disk was rotated so that the needle cut a wavy, grooved spiral on the wax. Copies of this were made for distribution.

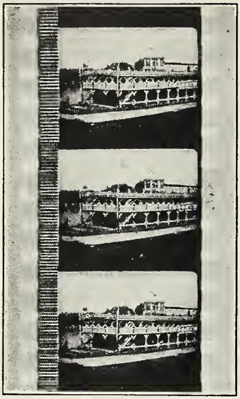


Electrical record making.

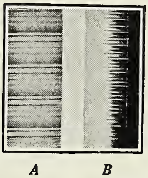
Now that amplifying systems have been perfected, we have another method of recording sound on disks. Sound is reproduced in front of one or more microphones. The resulting pulsating current passes through an amplifier. The strengthened current bearing the characteristics of the sound then go to an electrical recorder where the pulsations of the electric current are transformed into mechanical vibrations. These vibrations are carried by means of a special cutting needle to a disk. If many copies are desired, a master record is made from which duplicates can easily be taken. For some purposes only a single record is desired. This may be cut in an aluminum disk. Disks of this kind are much used in schools for pupils to study their own speech defects.

Disk Records and Sound Pictures. You are familiar with "This is an electrical transcription," which reaches you over the radio. It means an electrically recorded program is to be given from a disk record. In one system of sound pictures, disk records are made, by the principle shown on page 331, at the same time the picture is taken. Both are reproduced together to give the effect of the original production.

When a disk is used for sound and a film for the picture, if the film is damaged so a piece must be cut out, a strip of blank film must be put in to fill out the space. Otherwise the sound will not synchronize with the picture. If the sound were recorded on the film, both picture and sound could be taken out together.

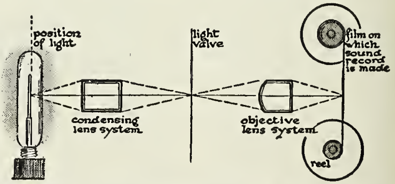


Photograph of one form of motion picture film on which is attached a sound record.



Two types of sound records made on films. *A*, varying density, and *B*, varying width.

Sound Records on Film. A method has been developed by which light is used to make records of sound on films, which can be used to reproduce the original sounds. The sound is first picked up by microphones which produce the fluctuating current just as a telephone transmitter does. This fluctuating electric current, which varies in strength and character corresponding to the sound which produced it, is carried to a *light valve* placed between the source of light and the film. By the opening and closing of the valve the moving film receives a series of exposures, determined by the size of the opening in the light valve, which in turn is determined by the sound.



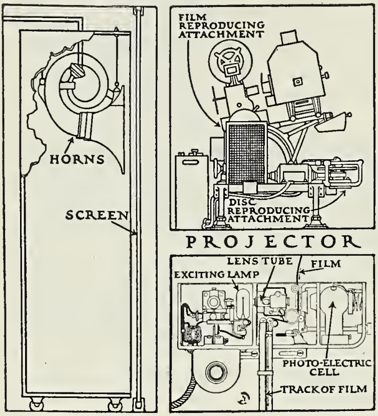
Arrangement of essential elements for making a sound film. Try to explain the process.

One form of light valve consists of two parallel flattened wires held in a magnetic field in such a way that when a current of varying strength passes through them, they will move and act as a shutter to the light gate through which light must pass to reach the film. The intensity of light is the same, but the length of each line exposed varies. This makes a band of varying width on the film shown in B in the illustration. Another type of recording produces a band of constant width with varying intensities as shown in A.

The Photoelectric Cell. In order to convert the sound record on the film back into sound, it is necessary to have a means of using light rays to create sound. This is possible by means of a device called the *photoelectric cell.* This is a special vacuum tube having two wire terminals. One of these ends in a loop or ring of wire in the center of the bulb. The other connects with a deposit of the metal potassium, which covers a portion of the inside of the tube. When a high-voltage battery is joined to the terminals — the positive pole to the wire ring and the negative to the potassium deposit — no current will flow in the dark, but if light falls upon the potassium, it starts a stream of electrons toward the wire ring. This is equivalent to "closing the circuit," and a current flows. The important thing about this cell is that *the strength of the current varies exactly with the intensity of light received.* The cell responds to the light stimulus instantly and cuts off the current as quickly when the light stops. The fluctuating currents are able when amplified to set up mechanical vibrations which produce sound.

How the Record on the Film Is Changed Back into Sound. In order to reproduce the sound recorded on the film it is necessary to produce an electric current which has all the variations corresponding to pitch and loudness which are represented by the light and dark portions of the sound record on the film. Strong light in a narrow beam is sent through the film directly into a photoelectric cell. The amount and the variations of light which enter the cell are determined by the dark and light areas in the sound band on the film through which the light must pass. There are then set up in the electric circuit controlled by the photoelectric cell the variations which have the characteristics of the original sound. These currents are amplified and sent to a loud-speaker which reproduces the sound which made the record on the film.

Sound Pictures. In the talking motion pictures the sound record may be on the same film with the picture, on a separate film, or as we have seen on a disk like the ordinary phonograph record. But no matter which form of sound record is used, it is necessary to change this sound record into electrical impulses which may be converted into sound, and also to have a means of making the sound and the picture keep step. This latter is sometimes accomplished by the use of two motors: one operating the picture film, and the other operating the sound film or disk record, although when the sound is recorded on the edge of the picture, the second motor is not needed. In the sound-picture theater the loud-speakers are placed behind the screen on which the pictures are shown, in order to make it appear as though the sounds were actually coming from the persons taking part in the play.



PROJECTOR

HORNS

FILM SOUND UNIT

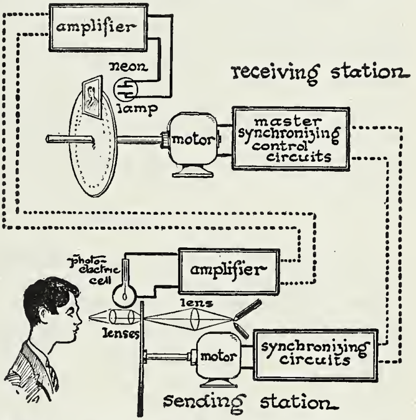
Western Electric Co.

Try to explain how a variable or pulsating electric current capable of making sound in the horns behind the screen is produced.

Television. Television — seeing at a distance — is a possibility. For many years television has been demonstrated for short distances and fairly good pictures of small size can be produced. But as yet the system has not been highly developed commercially. It is expected that many improvements will come and the cost made reasonable, so that television will be as common as the radio. It is not too much to expect that some day when one calls a party on the telephone, he will see on a screen in front of him a moving picture of the person with whom he talks. Also that when he sits at the radio listening to an account of a football game, he will see the teams in action so that he can watch the game in his own home.

Not only is the photoelectric cell essential in present-day television, but another device — the neon lamp — is equally important. The neon lamp is a glass bulb or tube containing neon gas in a partial vacuum and two metal plates connected to wires which pass through the glass to the outside. A high-voltage current brought to the plates will cause a glowing light which continues as long as the current continues, but ceases the moment the current stops. The intensity of light depends upon the voltage of the current.

In television a strong beam of light played upon a person's face is reflected into a photoelectric cell, setting up fluctuating currents of electricity. These currents are amplified and sent either by wire or radio to the neon tube at a distance. The beams of light which are thus produced in the neon lamp can be directed to a moving cylinder carrying sensitive paper, and a photograph will be printed upon it. This beam of light may be observed through a device called a scanning disk and the picture viewed directly, or it may be thrown upon a screen where it is seen by the observer. The neon lamp reproduces the variations of light and shade in the same relation to each other as they appear in the object in front of the photoelectric cells and in this way reproduces the image.



Showing a complete system of television sent by wire for individual reception. A small but powerful beam of light passing through the lenses is played upon the person. Reflection of this light into the photoelectric cell causes the pulsating electric currents which may be broadcast and received at a distance.

Other Uses of the Photoelectric Cell. Probably the greatest present-day use of the photoelectric cell is the production of sound pictures. However, it has many other uses. It is used in sending photographs by telephone wires and by radio. The first motion pictures of the arrival of Scott and Black in Australia, after their record-breaking flight from England in 1934, were sent back to England by radio. Pictures are sent daily across the continent for the press by wire.

Interruption of a beam of light, which is directed into a photoelectric cell, may shut off a current of electricity. This action may in turn be the cause of closing another circuit, which can perform almost any desired action. People may pass a certain place and interrupt a beam of light which was entering a photoelectric cell. They are automatically counted as they pass by. Photoelectric cells may be used to control traffic lights, to turn on burglar alarms, and to flood airports with light when an incoming airplane wishes to land. They will match delicate shades and tints of color more accurately than the human eye, or will regulate the heating of metals to a certain desired degree of temperature because of the color of the molten metal at a certain heat. They will open or close doors, stop or start machines, file and sort cards, ring fire alarms or time races, and in hundreds of other ways make our machines more efficient.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

intensity
controlled
retina
currents
record
perseverance
photoelectric
ring
sound
electrons
film
vibrations
power
disk
valve
voltage
slowness
light
pupil
potassium
persistence
phonograph
iris
electric
key
battery
rapidity
electricity
protons
variation
radium
reproducing

One terminal of the photoelectric cell ends in a wire (1)____ and the other is connected to a coating of (2)____. Stimulation produced by (3)____ starts a flow of (4)____ towards the wire (5)____ in the center of a (6)____ cell. Variation in (7)____ of light is produced in the neon lamp by variation in the (8)____ of the electric current passing through it. The phonograph pickup changes mechanical (9)____ into varying electric (10)____ which can be amplified and changed into (11)____.

Sound changed to its equivalent in (12)____ current may mechanically open and close a (13)____ so that various exposures on a film will produce in a series of light and dark lines a (14)____ of the sound. When a beam of light is sent through this film to a (15)____ cell, the interruptions of light caused by the dark lines cause a fluctuating (16)____ current capable of producing (17)____ in a loud-speaker. In "talking pictures" sound may be recorded on the (18)____ or on a (19)____ similar to the (20)____ record.

PROBLEM TEST

The photoelectric cell is coming to have many practical uses. *Try to explain how it can do the work expected of it in the following cases. Suggest what supplementary equipment is needed, if any.*

1. To determine the time of exposure needed in photographic work.
2. To transmit pictures by radio.
3. To have the water at a bubbling fountain start running when one leans over to drink.
4. To count the people entering a lecture hall.
5. To produce a record of sound on a moving-picture film.

◆

THE REVIEW SUMMARY

The review outline covers many interesting topics which come up in your everyday life. Try to make the outline complete and put your own individuality into it. The following are suggested as some of the important principles and generalizations that may be drawn from this unit:

1. Sound results from the vibration of matter within certain limits.
2. The human body has adaptations both for producing and for receiving sounds.
3. By using the principle of transforming one energy into another, electricity is an aid in communication.
4. The telephone makes use of a pulsating electric current.
5. The telegraph makes use of an interrupted electric current.
6. Sound can so make its imprint upon electrical radiations that they can reproduce the sound at some distant point.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × 2.*

I. **Sound is produced by vibration of:** (1) space; (2) air column; (3) strings; (4) heat; (5) vocal cords.

II. **The characteristics of sound may vary according to changing conditions as follows:** (6) pitch changes with vibration rate; (7) loudness varies with nearness; (8) intensity depends upon the amount of space through which vibration occurs; (9) quality changes with the overtones produced; (10) a bass note differs from a soprano in the amount of force used to produce it.

III. **The human ear:** (11) has a drum; (12) has a hammer; (13) makes sounds of low pitch; (14) helps us to detect odors; (15) is a useful agent in communication.

IV. **The electric telegraph:** (16) makes use of magnetic force; (17) requires the use of an electric current; (18) sends messages by means of interruptions in an electric current; (19) makes use of a microphone; (20) must have a carbon transmitter in the circuit.

V. **When we speak over the phone:** (21) sound is conducted along the telephone wires; (22) vibrations of the transmitter disk are produced; (23) a pulsating current of electricity is produced; (24) a detector tube rectifies the current; (25) the strength of the magnet in the receiver changes many times a second.

VI. **A three-element (filament, grid, and plate) tube may be used:** (26) to light the room; (27) to amplify weak messages in long-distance telephoning; (28) as a relay in telegraphy; (29) to detect radio waves; (30) to amplify radio waves.

VII. **Radio waves:** (31) are transmitted by the air; (32) are carried through space; (33) vary in intensity; (34) vary in frequency; (35) may be produced by electric sparks.

VIII. **In the detector tube:** (36) an electric current keeps the grid hot; (37) the plate is kept hot by the grid; (38) the filament is in complete circuit with a battery or other source of electricity; (39) the plate is joined to only one pole of a battery; (40) electrons from the filament pass through the grid to the plate at times and make a current in the loud-speaker.

IX. **In a public-address system:** (41) a carrier wave must be used; (42) amplifier tubes are necessary; (43) music records on the phonograph and microphone for voice may be connected to the same amplifier at the same time; (44) the microphone may be a long distance away from the amplifier; (45) the loud-speakers may be a long distance from the amplifier and from the microphone.

X. **The photoelectric cell is a device:** (46) for taking pictures by means of electricity; (47) for generating a large electric current; (48) used as a substitute for dry cells; (49) which produces electricity from light; (50) for changing electricity into light.

PRACTICAL PROBLEMS

1. Two friends go to different summer camps which are on opposite sides of a lake. How can they carry on communication with each other across the lake: *a.* when the sun is shining? *b.* after dark?

2. A merchant expects to receive a new lot of goods and he wishes to communicate the news to his customers. What are the different ways by which he may do this?

3. Make a diagram to show how you would change the wiring in an electric bell so that when the button is pressed, instead of ringing continuously, it will make only one stroke on the gong. This is a one-stroke bell.

4. Make a schematic diagram to show the essential steps in broadcasting transmission and in broadcasting reception.

LIBRARY RESEARCH READING

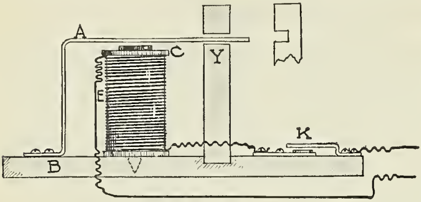
1. Hertzian waves; their discovery and significance.
2. Development of the vacuum tube.
3. Interesting uses of the photoelectric cell.
4. Marconi and his work.
5. The story of Bell and the telephone.
6. Difficulties of Field in laying the ocean cable.
7. Beginnings of written communication.
8. How a daily paper gathers the news.
9. "Electrical transcription."
10. Future of television.

SCIENCE FOR LEISURE TIME

1. **A tin-can telephone.** Punch a hole through the center of the bottoms of two tin cans. Put one end of a long wire through the hole from the outside. Twist the end around a short nail to hold it from being drawn through when the wire is pulled from the outside. At the other end of the wire — some 200 to 300 feet away — fasten the other can. The cans should be fastened so that the wire is drawn and held tight. The bottoms must be free to vibrate. When you talk into one can, the vibrations set up will travel over the wire, and a person holding his ear to the other can will hear you.

2. **Heliographing.** Devise a heliograph. Make two instruments and try to send messages back and forth from two hilltops, using a code you have prepared.

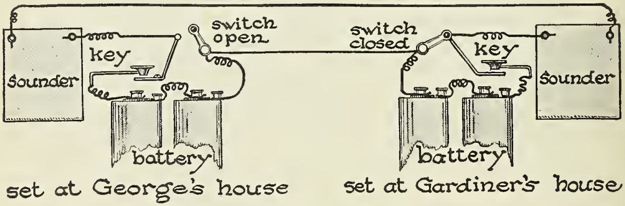
3. **A home-made telegraph sounder.** Can you devise a way for making a very simple telegraph sounder and key? The armature of the sounder and the key may be made from waste strips of galvanized iron which will cost you nothing at the tinsmith's. Use as thick a strip as you can find.



4. **A communication scrapbook.** Collect pictures and clippings that have to do with early and present-day methods of communication.

SCIENCE CLUB ACTIVITIES

1. **A telegraph line.** Follow suggestions in the diagram and set up a telegraph line from one room to another or from one boy's house to another. This is arranged so that dry cells may be used instead of "closed-circuit" batteries. When not in use, leave switches in "open" positions. Whenever one wishes to send a message, he opens his switch and uses the key. When he has finished, he must close his switch before a message can be received.



2. **A call signal.** Devise a way of connecting an electric bell and switch into each station of the telegraph line described above so that a person at some distance from the sounder can hear the bell, which is a call for him to take a message.

3. **Learning code.** Join a pair of telegraph sounders and keys in circuit and practice sending the Morse code.

Join a pair of buzzers in circuit and practice sending International code. One person in turn at each instrument tries to read what the other sends.

4. **Debate questions.** Arrange to debate one of these questions:

Resolved: That radio beacons will be of more service than lighthouses to the United States and to Europe in the next 100 years.

Resolved: That the telephone is a more important invention than the incandescent lamp.

Resolved: That the ability to receive eye signals is of more importance to man than the ability to receive ear signals.

5. **Excursions.** Arrange for club members to visit the local telephone exchange or a broadcasting studio.

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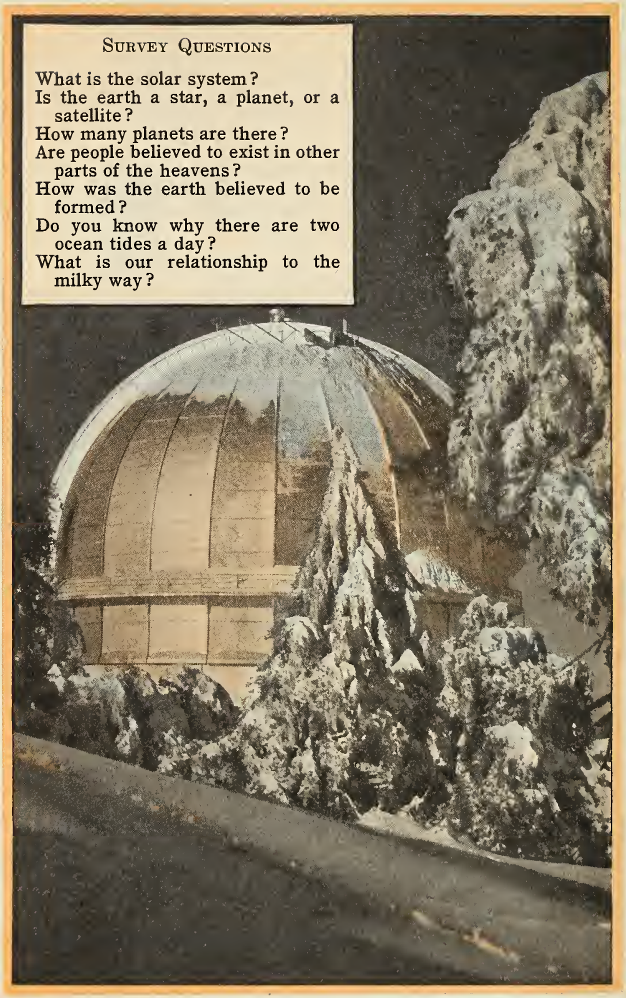
Survey Questions

What is the solar system?
Is the earth a star, a planet, or a satellite?
How many planets are there?
Are people believed to exist in other parts of the heavens?
How was the earth believed to be formed?
Do you know why there are two ocean tides a day?
What is our relationship to the milky way?



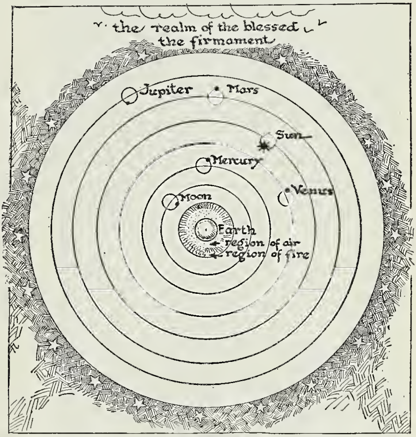
John Muir Technical High School

UNIT XI

GETTING ACQUAINTED WITH OUR NEIGHBORS IN SPACE

PREVIEW

We know today that our world is an almost round ball, revolving in space about the sun, but it was only a few centuries ago that most people believed the world was flat. It took a great deal of courage for Columbus, in spite of his belief, to sail toward the west when most people believed he would fall over the side of the flat surface of the earth. Yet the idea of the earth being a ball is a very old one. Two Greek philosophers, Pythagoras and Aristarchus, held theories that the sun was the center of the universe and the earth revolved around it. Pythagoras lived about 500 years before Christ and Aristarchus lived about two hundred years later. But this idea was too advanced for other philosophers. The famous Ptolemy, a philosopher of Alexandria, who lived 150 years after Christ, thought the earth was a sphere, but he believed it was fixed and the planets revolved around it.



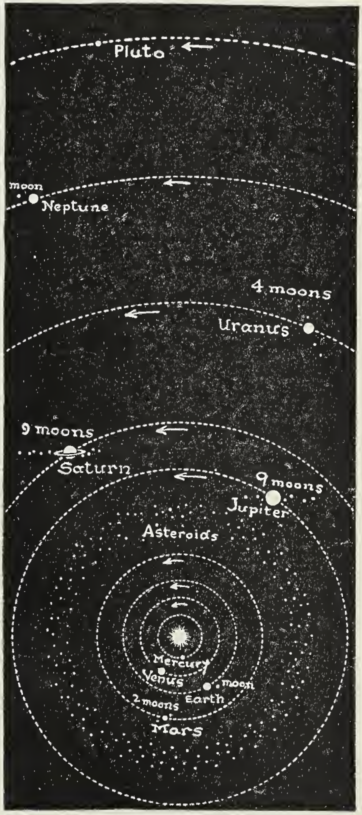
The philosopher Ptolemy thought the earth was a fixed sphere and that all of the planets (including the sun) revolved around it. He believed that each planet also revolved on a small orbit of its own, shown in the diagram as smaller circles. How does this compare with our present knowledge?

It was not until the sixteenth century, nearly 2000 years after Pythagoras, that Copernicus, a Polish astronomer, gave the world the idea of a fixed sun with planets revolving around it. Copernicus had no telescope — none as yet had been invented — but he cut slits in the walls of his house through which he observed the passage of stars across a certain portion of the sky. He published in 1543 a book called *The Revolution of the Celestial Orbs*, which may be said to be the foundation of our present knowledge of astronomy.

Just as other great scientific discoveries have come as the result of long, hard labor on the part of several men who built on the discoveries of each other, so it has been with astronomy. The complete idea of our solar system was long in coming. Kepler, who worked out by mathematics the law of the orbits of the planets, proved these to be elliptical instead of circular. Galileo, who was the first great experimenter, made the first real telescope. With this he proved that the planets actually revolved around the sun. Then came Newton, whose researches on gravitation could be applied in the field of astronomy. But in comparatively recent times scientists have discovered that this solar system of ours with its sun and attendant planets is only a very tiny part of the multitude of stars that surround us in space. The Milky Way has always been known. First it was thought to be a girdle or belt across the heavens, later a pathway for the souls of the dead who traveled heavenward. Now we know it is composed of a great multitude of stars. Millions of them forming, with our own solar system, a galaxy containing between 20,000,000 and 100,000,000 of stars. And when we realize that this galaxy of ours is but one of many in the heavens, some of them being millions of light years away, we are lost in wonder at the magnitude of the starry heavens. No wonder the ancient Hebrew writer said, "Look now toward the heavens and tell the stars if you be able to number them."

The interesting things in astronomy are so many we cannot hope to get more than an introduction to them. The topics discussed in this book are quite different from those you have studied in the last two years. It will help you in your present study to recall some of the important facts which were taken up in your earlier work.

1. Space is vast.
2. The stars though billions of miles apart are exceedingly numerous.
3. We are aware of the stars because of the radiations they send out.
4. The rotation of the earth allows us to view the entire expanse of the heavens and also produces an apparent rotation of the stars.
5. A light year is the distance light travels in one year.



What are the relative distances of the planets from the sun?

PROBLEM I. WHAT IS OUR SOLAR SYSTEM?

The Solar System. There are a number of bodies which surround us in space that, with the exception of the moon, never come nearer to us than 25,000,000 miles. This seems a very great distance, but by comparison with 25,000,000,000,000 of miles away, or with distant galaxies 6,000,000,000,000,000 of miles away it seems to be quite near. Everything, after all, is relative. Stars are like our sun. Bodies which revolve around the sun, as does the earth, are called planets. They vary in size, speed, and distance from the sun. They differ in surface conditions, atmosphere, and the number of attendant moons or satellites.

Gravitation and the Solar System. Our weight would vary with the planet on which we lived. Weight on the earth is the measure of the earth's attraction for us. All bodies in the universe attract each other; in other words, every heavenly body attracts every other body. This attractive force is called gravitation. If a body is doubled in size, the attraction is doubled, but if the bodies are moved apart to twice their original distance, the attraction is only one fourth as great. It is the attraction of the sun for bodies moving around it that keeps them from going off into space. We find large bodies similar to the earth called *planets* which revolve around the sun, each having its own orbit or path. Besides these planets there is a group of some eight or nine hundred bodies called planetoids, and in addition, moons and other dark bodies of small size which are scattered all through space. These latter bodies often come so near the earth that they are attracted to it, and so we see them as meteors. Other luminous bodies which visit us periodically are called comets. All these bodies together, the sun, the planets, the planetoids, the moons, meteors, and some of the comets make up a group of heavenly bodies called the *solar system.*

Origin of the Solar System. Astronomers have for many years been interested in theories which would account for the origin of the solar system. La Place toward the end of the eighteenth century proposed a theory called the Nebular Hypothesis. According to this theory, all the matter in the solar system was at one time a body of hot gaseous material. This material was rotating, and as it rotated it shrank, and from time to time rings of matter were thrown off from it. Later these rings contracted so that finally a globe-like mass of gas resulted from each of them. Such a body, still contracting and rotating, gradually formed planets, and as one or more rings of gas were thrown off from it, one or more moons would be produced. The ring having material for a planet between Mars and Jupiter evidently could not all be brought together in one body, and so we have hundreds of smaller bodies — the planetoids — there. The Nebular theory has been discarded in favor of the so-called Planetesimal Hypothesis proposed by Professors Chamberlain and Moulton of Chicago University in 1905. This theory assumes that at one time a large star in passing quite close to the sun raised a huge tide of matter, and that this material as it was drawn out instead of falling back into the sun, continued for a time as great spiral arms reaching out into space on opposite sides of the sun. In time, matter collected about the denser masses within these arms and formed rotating bodies which continued to move in elliptical orbits around the sun. A planet thus formed continued to attract matter from near-by space, just as the earth is now collecting material in the form of meteors that fall into it. Some of the larger bodies might have had such speed that as they came near the planet, they would circle around the planet instead of falling into it, and thus form moons. Although much matter was drawn into these larger bodies, some continued scattered through space, and this forms today our meteors.

Other Theories of the Earth's Origin. A theory suggested by Dr. Ross Gunn of the U. S. Naval Research Laboratory makes a large star the source of our whole solar system. The star in some way increased its rotation speed until it flattened, elongated, and finally separated into one large remnant, our present sun, and many smaller bodies, our present planets.

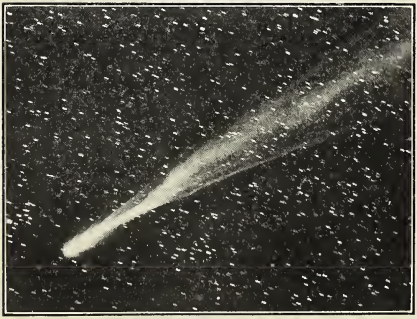
Another new theory for the origin of the earth has been proposed by Dr. Harlow Shapley of Harvard. According to this theory, the sun, moon, earth, and other planets all came from the same spiral nebula. In the older theories the sun was the source of the planetary bodies and therefore was older. According to this new theory, all bodies in the solar system are of the same age. Our whole solar system is the progeny of a "secondary swirl or eddy of the parental spiral nebula out of which the local galaxy or milky way may be supposed to have generated."

Meteors. Almost every boy and girl has at some time seen what is called a "shooting star." This has the appearance of a star moving rapidly across the sky or downward toward the earth, followed often by a trail of light. In reality, it is not a star at all, but is a meteor. There are throughout the space that surrounds the earth and other planets countless millions of small bodies of matter moving at tremendous speed. They are dark bodies and are too small to be seen. They are so small and so far apart, that they obstruct the light from the sun or stars but slightly. The earth is continually coming so near to some of them that they are attracted to it by pull of gravity, and thus fall to the earth. The intense heat produced by friction between the air and the moving body causes it to glow. The majority of meteors are actually vaporized or burned in the air to dust, which slowly settles to the earth. But a few meteors, some of them weighing tons, have reached the earth. The solid rock, after reaching the earth, is called a meteorite. A variety of elements are found in meteorites, but the chief ones are the metals, iron and nickel. Meteoric matter seems to be more plentiful at certain points along our orbit. Also it is believed that there are groups or swarms of meteoric bodies that go through space in orbits, and when we pass through such a swarm we see "meteoric showers."

Museum of Natural History

A meteorite made of iron. This is one of the largest ever found.

Comets. Comets are rarely seen; they are visitors to our solar system. Some come and leave and are never seen again, others make periodic returns. Brooke's Comet visits us once in seven years, but Halley's Comet comes


Yerkes Observatory

A comet. How do we know the tail is gaseous? Why do the stars all look elongated in one direction?

around only once every 75 years. Only the larger comets are seen with the naked eye. Comets are gaseous bodies having a dense nucleus or head, and a less dense tail. They are so rare or thin that stars may be seen through them. All comets circle the sun, and the tail always points away from the sun.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

moon
planetoid
matter
meteors
facts
light
space
planets
dark
body
sun
shooting
theories
gravitation
planetoids
comets
bright
origin
luminous
satellite

Bodies revolving around the (1)____ as does the earth are called (2)____. The attraction of one heavenly (3)____ for another is called (4)____. The only (5)____ bodies ever found in the solar system besides the sun are (6)____. No one knows the (7)____ of the solar system but there are several (8)____ to account for it. Dark bodies in (9)____ captured by the earth produce a streak of (10)____ in our atmosphere. They are called (11)____ stars, but in reality are (12)____.

PROBLEM TEST

How Clearly Do You Think?

Edmund offers three statements which he has thought out. Whether you agree or disagree, tell in each case your reason for agreeing or disagreeing with him.

1. All bodies in the solar system with the exception of the sun and comets are dark bodies. The moon gives us light therefore it does not belong to the solar system.
2. The attraction of heavenly bodies is decreased as the distance between them increases. If the earth were twice as far away from the sun, man would weigh only $\frac{1}{4}$ as much as he does now.
3. Comets travel at a tremendous speed. The earth has a speed of 11 miles per second. Should a comet and the earth come together, the shock would produce sufficient heat to melt the earth and possibly change it to a gas.

PROBLEM II. WHICH PLANET PROVIDES THE BEST HOME FOR MAN?

There are nine planets, all dark bodies, having many properties in common with the earth, revolving around the sun. A comparison of significant facts about the planets follows.

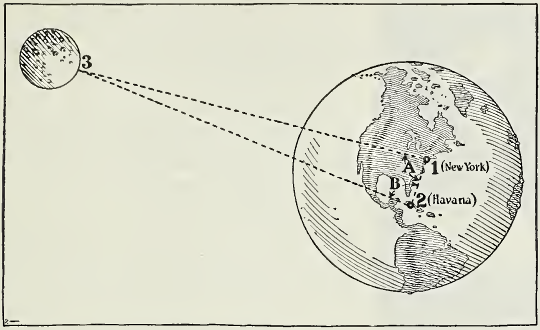
THE PLANETS, SUN, AND MOON

Names	Size	Distance from Sun. Average in Millions of Miles	Rotation on Axis. Length of Day	Time to Revolve around Sun	Number of Moons	Density
	Diameter in Miles					Water=1
Mercury . . .	3,000	36	?	88 da.	none	3.7
Venus	7,600	67	?	225 da.	none	5.2
Earth	7,927	93	24 hrs.	365.3 da.	1	5.5
Mars	4,200	141	24.5 hrs.	1.9 yrs.	2	3.9
Ceres, an asteroid	488	257		4.6 yrs.	none	
Jupiter . . .	88,700	483	9.9 hrs.	11.8 yrs.	9	1.3
Saturn . . .	75,000	886	10.2 hrs.	29.4 yrs.	10	.7
Uranus . . .	30,900	1782	10.7 hrs.	84 yrs.	4	1.3
Neptune . . .	33,900	2793	15 hrs.	164 yrs.	1	1.3
Pluto	2,400?	4000	?	250 yrs.	?	?
Sun	864,000	——	25 da.	——	——	1.4
Moon	2,159	93	27.2 da.	1 yr.		3.3

Are Planets Stars? Real stars give out light of their own. None of the planets are hot enough to give out light. They are visible because they reflect sunlight and appear bright because they are near the earth. They follow a path across the sky very close to that followed by the sun and moon. When Mercury and Venus are morning stars you can see them in the east just before sunrise and when they are evening stars you see them in the west just after sunset. This is because they are so near the sun. Mars, Jupiter, and Saturn because of their very large orbits may be visible in a part of the sky far from the sun.

When viewed through a telescope, the planets nearest to us look like disks, but real stars because of their distance appear only as luminous points. Movements of air refract and break up the light from distant stars, causing them to twinkle. Planets, which are nearer, do not twinkle.

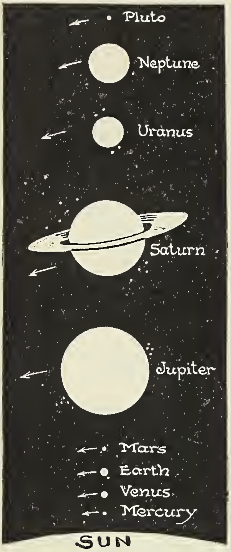
How Distance to Planets Is Measured. The method of measuring distances to other planets is based on what the mathematician calls *triangulation.* That is, two points on the earth, some distance apart, are selected and from them careful observations are made of a given planet at a certain moment. The angles between these points and the planets being measured, it is possible with a knowledge of trigonometry to calculate the distance to the object.



The length of the base line 1–2 and the sizes of the angles *A* and *B* are all the mathematician needs in order to tell how far away body 3 is. Do you know why?

Mercury. Mercury, the nearest planet to the sun, revolves about it once in 88 days, and like our moon, which keeps one side toward the earth, it also always keeps the same side toward the sun. One side of Mercury is perpetual day and the opposite side is perpetual night. Because the axis is inclined to the plane of its orbit, there is a little movement of the light boundaries. As a result, there is a variation in light and darkness for about one fourth of the surface of Mercury. Mercury has very little atmosphere to temper the sun's terrific heat or to carry stored heat in winds around to warm the intensely cold dark side. Because its path is more elliptical than that of the earth, Mercury is 15,000,000 miles nearer the sun in summer than in winter. Thus while its temperature in the sun may be above 400° F. in winter, the rocky surface might rise to above 800° F. in summer. This is hot enough to melt lead, zinc, and tin. It is evident that life, as we know it, cannot exist on Mercury.

Venus. Venus is but a trifle smaller than the earth, of about the same density, and also reflects about the same amount of sunlight. She has an atmosphere, and has so many likenesses to the earth that she has been called the earth's twin sister. While Venus is so much nearer the sun that she receives about twice as much heat and light as the earth does, yet the dense clouds in her atmosphere probably absorb half of this energy.



The curved surface of the sun is shown at the bottom of this diagram. Compare the size of the planets with that of the sun.

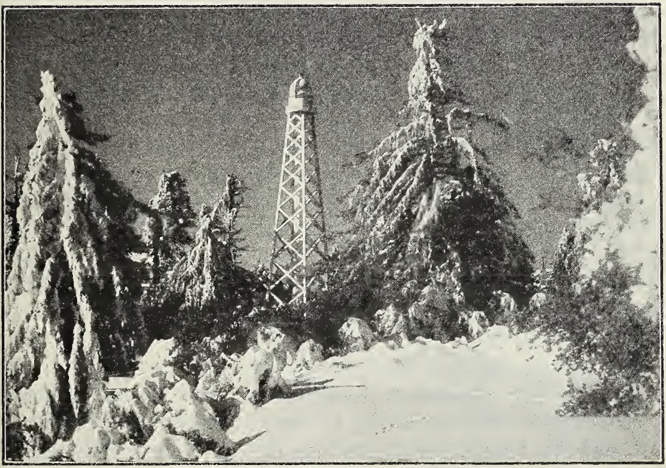
It is difficult to learn much about Venus. Oxygen is not known to exist there, but there is much carbon dioxide. This might make plants flourish and if they give off much oxygen some type of animals might live below the clouds. Some think Venus rotates on her axis once in a trip around the sun, or once every 225 days. This would make one side always day, as is the case with Mercury. Others believe that Venus rotates once in about 24 hours, upon an axis which is vertical to the plane of her orbit, around the sun. In that case there would be no change in seasons. The planet would be divided into zones of perpetual winter, of perpetual spring, and of perpetual summer. The orbit around the sun is almost a perfect circle, and so the variation of heat and light during the year is slight.

Because of her size and nearness to the sun, Venus reflects enough light to appear as one of our most brilliant evening or morning stars. But there are short periods when Venus cannot be seen at all. These periods of darkness occur when Venus is between us and the sun with the dark side toward us. This will happen about every one and a half years.

Earth. The earth is the third planet from the sun. It is the nearest planet that has a moon. Its orbit is so slightly elliptical that if it were drawn to scale, the eye could hardly detect that it was not a true circle. The variation in distance from the sun is from 91,500,000 miles in winter to 94,500,000 miles in summer. The earth travels, with us as passengers, at a rate of over 1,500,000 miles a day along its orbit.

Mars. Mars has a diameter but little over half that of the earth and has a surface area about one third that of the earth. The axis of Mars is inclined much like that of the earth, and the rotation on the axis is just a little over 24 hours. Thus day and night and the seasons on Mars would be of the same general character as on the earth. But since it takes Mars about two or more years to travel around the sun, its seasons are about twice ours in length.

Mars is 48,000,000 miles more distant from the sun than the earth is. Because of its greater distance from the sun, the intensity of sunlight on Mars can be only about half that on the earth. The atmosphere there is thinner than ours. This would allow much heat and light to reach the surface of Mars during the day, but would allow so much to radiate that at night it would become very cold,



Class in photography, John Muir Technical High School, Pasadena, Calif.

One of the telescopes at Mount Wilson, where some of our most important astronomical observations have been made. What notable telescope is located there? It makes the moon appear to be only 25 miles away.

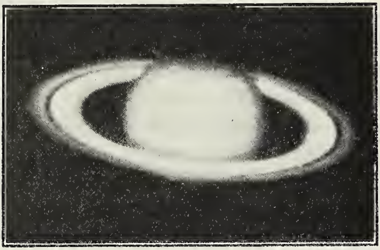
perhaps below zero. There appear to be ice caps at the poles, which decrease in area during the summer season. Its red color may come from the immense red areas of desert sands. Certain lines on Mars are thought by some astronomers to be huge canals made by people. Dark strips are thought possibly due to vegetation but there is no certain evidence of life on either Mars or Venus.

Mars has two moons, but they are very small, one about ten miles, and the other not much over six miles in diameter. These moons are so near Mars that they revolve around the planet, one in thirty hours, and the other in seven and one-half hours.

Planetoids (Asteroids). Beyond Mars, at a distance from the sun where we might expect another planet, are a large number of small planets, called *planetoids*, all of them too small to be seen with the naked eye. About 1500 of them have been discovered. The largest is Ceres, 480 miles in diameter. Only four of them seem to have a diameter over 100 miles. They have a great variety of orbits and one of the planetoids, Eros, sometimes passes over within the orbit of Mars. All the material found in the planetoids would make a fair-sized planet. It is possible that they never come near enough to each other to unite and form a planet.

Jupiter. Jupiter is the largest planet, but its mass is only about 314 times that of the earth. It has nine moons, two of which are larger than the planet Mercury. Four of the nine moons are readily seen through a small telescope, but the other five are very small. Jupiter is so far from the sun that the heat and light it receives from it is small. It receives only $\frac{1}{27}$ as much light as the earth. Recent studies show rather conclusively that Jupiter is a cold planet, probably never getting above 200° F. below zero. Bands of gaseous matter making up the atmosphere have long been observed to pass across the face of the planet, but only recently has an analysis of the gases by a careful study of the spectrum revealed the fact that the atmosphere has no oxygen or carbon dioxide. Instead it is chiefly composed of the two gases ammonia and methane, neither of which can sustain the kind of life that we know. There may be lakes of liquid methane or liquid ammonia on Jupiter. There are still many questions that the astronomers are not able to answer with certainty, because Jupiter, even when nearest to us, is nearly 400,000,000 miles away.

Saturn. Saturn has a diameter of more than nine times that of the earth. The striking thing about Saturn is the fact that it is surrounded by three distinct rings, which are possibly made up of gases, dust, or millions of small particles revolving like so many moons. This material will probably become a part of the planet within a few million years. The rings may bear the same relation to a moon that the planetoids do to a planet. Saturn has ten moons. It is probably a cold body with temperatures averaging 300° below zero.



Yerkes Observatory

Saturn, showing its rings. These rings are believed to be made up of small masses of matter in motion. What will eventually happen to these particles of matter?

Uranus. Uranus is four times the size of the earth, but so far from the sun that, as somebody has stated, the light Uranus receives from the sun is to the light that the earth receives from that body as the light of one Christmas candle is to the light given out by five 500-watt lamps. With a probable temperature of 340° below zero, we will not speculate about life there.

Neptune. Neptune is so far away it cannot be seen without the aid of a telescope. It is about the size of Uranus. Neptune receives approximately one thousandth as much light from the sun as the earth does. It is even colder there than on Uranus.

Pluto. Pluto is about one quarter the size of the earth and is nearly 4,000,000,000 miles from the sun; so far distant that no telescope is able to show any disk as can be done with the nearer planets. It takes about 250 of our years for it to make one revolution around the sun. Pluto is now approaching us and the sun. It is getting more light and will continue to grow brighter until 1989. At that time it will go away from the sun, and for the following 125 years will continue to grow fainter.

The Home of Man. If you look over the solar system, do you find any other planet or any moon that you think might make a desirable dwelling place for man? Mercury is surely too hot, but how about Venus? Although we cannot tell what its real surface under its atmosphere is like, are there possibilities of life there? Mars appears to offer conditions under which man might live, but how would the difference in gravity and the rarer air affect man? All the other planets, Jupiter, Saturn, Uranus, Neptune, and Pluto, are so far from the sun that they get very little radiation from it, and unless they have heat of their own, their surface temperatures are probably several hundred degrees below zero.

Not only Jupiter, but Saturn also is believed to have an atmosphere made up chiefly of two noxious gases: ammonia, the sharp pungent gas used in producing artificial cold, and methane, which has been an active agent in many serious mine explosions.

Are There Other Systems of Planets? We have learned that the sun is a star and that there are millions and millions of stars which give out light and heat just as our sun does. With this in mind we quite naturally ask if all these stars have families of planets. If they do, it is probable that some of the planets have reached a stage of development similar to that of the earth. According to the nebular hypothesis the production of planets about a star or central sun was a natural process of development. But under modern theories the probability of a system of planets developing from a star is very small. As astronomers increase their knowledge of stars and planets, their belief in the existence of other systems of planets seems to be diminishing. What if our system is the only one which has planets? What if our earth is the only planet in the whole of space where man exists?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

six
three
two
no
smallest
striking

many
large
beautiful
moons
planetoids
distance

Neptune
Venus
Jupiter
Mercury
Mars
Pluto

Saturn
largest
orbits
rings
Juno
ordinary

No two planets are the same (1)____ from the sun, nor do they have (2)____ of the same size. The planet nearest the sun is (3)____ and the most distant one is (4)____. There are (5)____ planets nearer the sun than the earth. Mercury is the (6)____ and Jupiter is the (7)____ planet. The planet that appears always to be under a cloud is (8)____. The most (9)____ and to many the most (10)____ view one can have through a powerful telescope is that of (11)____, which differs from all other planets in being surrounded by three (12)____. If any planets besides the earth have people on them, they most likely are Mars and (13)____.

PROBLEM TEST

Cora offers three statements which she has thought out. Whether you agree or disagree, tell in each case your reason for agreeing or disagreeing with her.

1. One evening I saw Jupiter through a small telescope. There were two bright moons on one side and one on the other side of it. Two hours later I looked again and saw the two on one side but this time there were also two bright moons on the other side. There are three possible explanations of this: *1.* The moon's light may have changed in brightness. *2.* One side of the moon is always dark and I was looking at the dark side. *3.* A meteor or planetoid came between me and the moon, cutting off its light.
2. There are hundreds of small bodies in space revolving in a path around the sun in a space where astronomers think there should be a large planet. The only way to account for their presence there is to suppose that they are the fragments of an exploded planet.
3. In centrifugal motion, the denser matter tends to be thrown farther from the center than the lighter matter. By the nebular theory the earth and moon were at one time a single body from which the moon was separated. Since the moon is all rock, with no water or air, its density is greater than that of the earth and so it may have been thrown off from the whirling earth. This seems to support the nebular theory.

PROBLEM III. WHAT THE MOON DOES FOR MAN

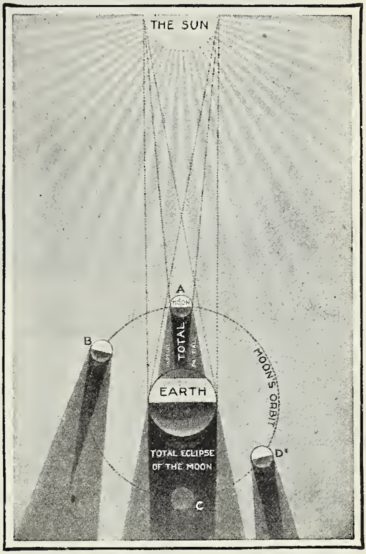
Our Satellite — the Moon. Compared to the distance of the sun, the moon is a very close neighbor, being only about 240,000 miles away. It is quite different from the sun, since it is a solid, non-luminous body. Our largest telescopes have brought it so near that it looks not more than 25 miles from the earth. With these telescopes we see surface markings resembling huge pits or craters of volcanoes. There is no evidence of life or water and no indications of any atmosphere. It is a cold body and reflects light from the sun to us. It revolves around the earth once in 29½ days and goes with the earth around the sun once a year. In traveling around the earth, the same side of the moon always faces the earth, so there is one side of the moon we never see.

American Museum of Natural History

The surface of the moon.

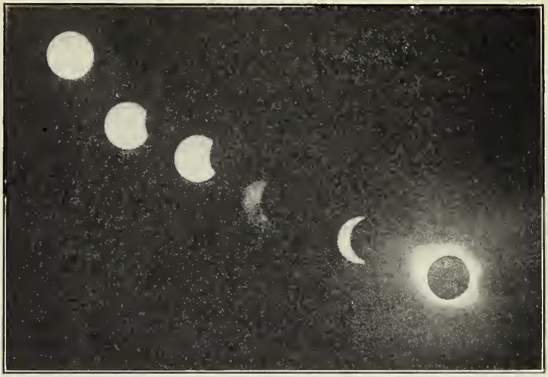
Eclipses. Without a moon there would be no eclipses. But with a moon, we have two kinds: an eclipse of the sun when the moon passes between the earth and the sun, and an eclipse of the moon when the earth passes between the sun and the moon. Both the moon and the earth cast long shadows back into space away from the sun. If the earth moves into the moon's shadow, the light of the sun is cut off from that portion of the earth covered by the shadow. If the moon moves into the earth's shadow, the light of the sun is cut off from it, and we can see the result as the shadow moves across the moon's surface, gradually reducing the lighted area.

Eclipses of the Moon. The earth's shadow is so much larger and longer than that of the moon, that there are more eclipses of the moon visible to people on the earth than there are eclipses of the sun. They are also visible over a much larger area on the earth's surface. A total eclipse results when the moon passes entirely into the dark shadow, and a partial eclipse when the moon passes only part way into the shadow.



Eclipses of sun (*A*) and moon (*C*); diagram not on a uniform scale. In a diagram to scale, the sun, moon, and earth would be vastly farther apart. The fact that the sun's rays are not quite parallel has important results. Notice that the edge of each shadow, either total or partial, is a line extending to one edge of the sun.

Eclipses of the Sun. One of the most spectacular natural events that comparatively few people see more than once in a lifetime, is a total eclipse of the sun. A total eclipse of the sun is visible from only a very limited area of the earth's surface. The moon is so small that the tip of its cone-shaped shadow barely reaches the earth, and sometimes even falls short of it. The earth varies in its distance from the sun from 91,000,000 to 94,000,000 miles, and the moon varies in its distance to the earth from 223,000 to 252,000 miles. The relation of distances at any given time determines the length of the moon's shadow, and whether or not it will span the distance from the moon to the earth. People on the earth within the totally darkened area see a *total* eclipse. Then only does the beautiful corona of the sun become visible. In a much larger area a *partial* eclipse may be seen when the disk of the sun is partly hidden by the moon. On rare occasions, the darkened shadow of the moon is pointed directly towards some part of the earth, but it does not reach the earth. People who are back of this shadow



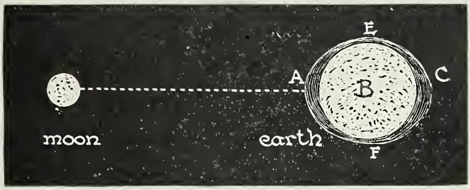
Wide World

Six photographs of the eclipse of the sun in 1932. These were taken at brief intervals. Which shows the total eclipse?

see the dark outline of the moon against the center of the sun, but with a ring of the lighted sun all around it. This is the *annular* eclipse.

Phases of the Moon. We frequently speak of the new moon and the full moon or its first quarter or the last quarter. These terms are known as the moon's phases and refer to the amount of the moon's surface that we can see at a given time. The sun always lights one half the area of the moon. The moon revolves around the earth once a month, passing nearly between the sun and earth in its journey. When it is about opposite the earth from the sun, the half which we see is entirely lighted; that is the full moon.

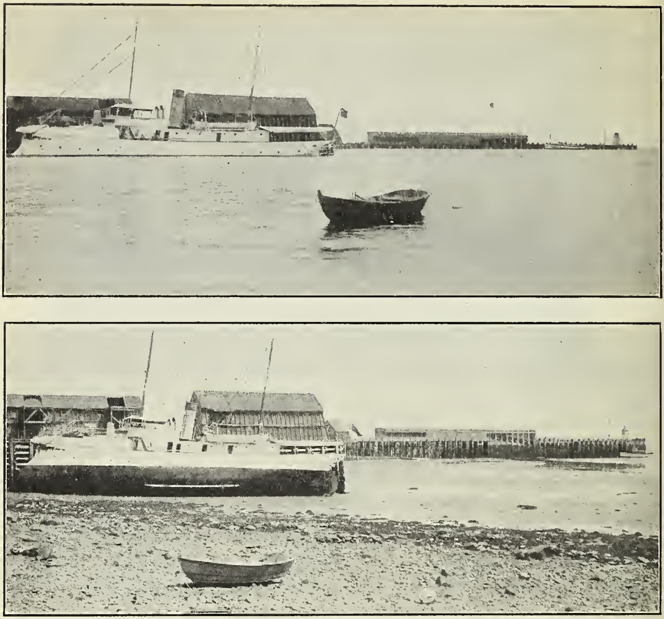
Tides. Those who have lived near the ocean are accustomed to seeing the water move in and rise on the shore twice a day, and then move out again. The attraction of the moon causes the water in the sea to be pulled up a few feet higher than usual. The earth is sometimes regarded as composed of a solid center of rock and earth. This is surrounded by a zone of water. Outside of the water is another zone of air. This idea is very nearly right except that only eight ninths of the earth's surface is water. But the water reacts to forces exerted upon it just about the same as it would if it entirely surrounded the earth. This being the case, we can see how the moon's attraction will pull on the water (A) with more force than upon the earth (B) which is more distant, also that it will pull upon (B) with more force than it does upon the more distant water (C). The result is that water at (A) is pulled away from (B), starting a high tide on the side of the earth under the moon. It will also pull (B) away from (C), causing the effect of a high tide at (C) on the side of the earth away from the moon. Since water is heaped up at (A) and (C), it will be drawn away from (E) and (F), which will at that time have low tides. While this is not a complete explanation of tides, it is sufficient to show one reason why high tides exist on opposite sides of the earth at the same time.



Read your text and then explain the diagram.

The sun also causes tides by its attraction. Sometimes it joins with the moon to make extra high tides called *spring tides.* At other times the sun and moon oppose each other by pulling at right angles and then they cause low high tides, called *neap tides.* The sun's tide is smaller than that of the moon. For the six hours that the tide water is flowing in toward the shore, we have the *flood tide,* and during the six hours that it is flowing out, we have the *ebb tide.* There are two flood tides every 24 hours.

Tides are of much practical importance to shipping. Many ports are dependent upon the deep water of high tides to allow vessels to reach their docks. Tides have much value in changing the water in estuaries and harbors. Much sea life is dependent upon the alternate covering and uncovering of the flats along our coast. In some parts of the world tides furnish water power for



These two pictures are of the same place at high and low tide. What do you know about the cause of tides?

grinding corn and wheat. In the case of producing tides, we can see that the moon makes many valuable contributions to the environment of man.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

planets
moons
stars
eclipse
autumn
spring
dark
lighted
sun
shade
work
light
ebb
making
flood
moon
visible
shadow
results
full

Our nearest neighbor in space is the (1)____ which can be seen only by (2)____ reflected from the (3)____. When the (4)____ of the moon touches the earth an (5)____ of the sun (6)____. The amount of the (7)____ surface of the moon which is (8)____ varies. A lunar (9)____ occurs when the earth is between the (10)____ and the moon. The most important (11)____ done by the moon is that of (12)____ tides. When the (13)____ and moon act together on the ocean, they produce the extra high (14)____ tides.

PROBLEM TEST

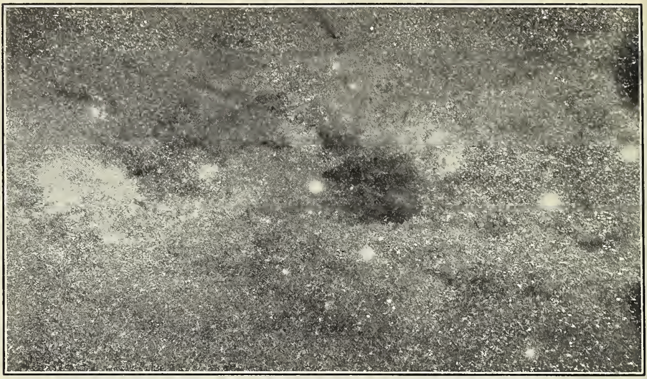
Muriel will test your ability to think clearly in these three questions. Give reasons why you agree or disagree with each statement.

1. If the moon were removed to a distance 500,000 miles from the earth:
    (*a*) The only eclipse of the sun would be an annular eclipse.
    (*b*) There could be no eclipse of the moon because the earth's shadow does not extend that far into space.
2. Since the moon always keeps the same face towards the earth:
    (*a*) It does not rotate on its axis.
    (*b*) One half of the moon's surface never receives sunlight.
3. When the sun and the moon are on opposite sides of the earth they will produce (*a*) neap tides and (*b*) the low tides will be lower than usual.

PROBLEM IV. WHAT IS THE EARTH'S RELATION TO THE MILKY WAY?

What Is the Milky Way? We have all seen the Milky Way extending like a belt across the sky. Large telescopes and new methods of photography have resolved this belt of light into a great mass of stars. Careful study also shows that towards the edge of the Milky Way the number of stars decreases greatly. This suggests that the Milky Way is part of a huge system of stars which is called a galaxy. From our own sun's position in space, astronomers have come to the conclusion that our solar system is a part of this galaxy. The stars we see with the naked eye are near-by stars in this same galaxy.

Distances in the Milky Way. We are located within but not in the center of this Milky Way galaxy, and the distance through to stars on the opposite edge is so far that it is estimated that it takes light 100,000 to 200,000 years to cross it. How many miles



Dark spots and lines seen in the Milky Way are probably due to dark bodies or dust clouds between us and the distant stars.

would that be? Let us see. Light travels roughly 186,000 miles a second. This multiplied by the number of seconds in a year gives 5,800,000,000,000 miles, the distance light travels in one year. Multiply this by 100,000, the number of years light must travel to cross this galaxy of stars in the MilkyWay, and we get the staggering number 580,000,000,000,000,000 (five hundred and eighty thousand millions of millions of miles), for the diameter of the Milky Way.

Form of Our Galaxy. Astronomers who have given much study to these groups of stars have reached the conclusion that while this galaxy of stars appears to resemble a disk wheel or a thin watch in form, it is in reality spherical. We are situated about one fourth to one third of the distance from the outer edge to the center. If we consider the whole galaxy as spherical, the majority of stars are in the equatorial regions, while toward the poles the stars are few and scattered. The brightness of the belt of stars we see is due to the fact that we are looking through the diameter of the dense portion of the galaxy. We can see with the unaided eye no farther than 3000 light years away. Stars near the center being possibly 20,000 to 40,000 light years away from us can only be seen by the aid of a telescope. The number of stars in this galaxy — the Milky Way — is estimated at 10,000,000,000 to 100,000,000,000 stars. Professor Jeans thinks that it is possibly even more than that.

The whole system revolves, each star being held in its course by the attraction of other stars. The stars near the rim require the longest time to complete their orbits. Our sun travels at about the rate of 200 miles a second and completes the journey around the center in about 2,000,000 years.

Dark Areas. Black objects if present in the distant heavens could not be seen. Dark bodies such as planets are believed to be small in comparison to the size of stars to be noticed. The planets of the solar system are so small compared to the sun that anyone at a distance of even a few light years could not detect their presence when looking at the sun. What is then the explanation of the dark figures which appear in various parts of the sky and appear like holes through the masses of stars? It is now believed that these dark "clouds" are really cloud-like masses of very fine dust particles which absorb light from the stars back of them. Astronomers think there are no large spaces which are dark because of the absence of stars, but that the light of those distant stars may be cut off from us by these dust clouds. It is one of these dark clouds that obscures a part of the Milky Way and causes an apparent separation into bands. The illustration shows a conspicuous dark area in the Milky Way. When you look into the southern sky in July or August, note the dark area separating the Milky Way into two belts.

Mount Wilson Observatory

A spiral nebula. The stars seen are nearer or more distant, but not a part of the nebula.

Other Galaxies in Space. Astronomers believe that our galaxy is only one of many — perhaps millions of them. The reason for this belief is the fact that scattered through space there are many spiral nebulae which, under the great magnification of large telescopes, appear to be great collections of stars whisking through space like pinwheels at tremendous speed. The great nebula in the star group Andromeda, for example, is thought to be made up of millions of stars, and is at least 1,000,000 light years away. Over *two million nebulae* have already been discovered so that our own galaxy of stars may be only one of many millions of these galaxies, all forming a great super-galaxy made up of all the stars. It makes us realize our insignificance in the universe when we think of our small place in the solar system, but what can we say when we think of galaxies and super-galaxies, so vast is space around us!

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

microscopes
100,000
1500
one half
one third
moon
sun
stars
meteors
center
space
galaxy
existence
belong
rim
telescopes

The Milky Way is a (1)____ of stars of which the (2)____ is a member. We are located within this galaxy possibly (3)____ the distance from the rim to the (4)____. All (5)____ seen with the naked eye (6)____ to the same (7)____ as does our sun. The diameter of our galaxy may be (8)____ light years. Very powerful (9)____ have revealed the (10)____ of many other galaxies in distant (11)____.

◆

REVIEW SUMMARY

In order fully to prepare yourself to discuss this unit you need a detailed outline. Some of the generalizations you will undoubtedly recognize are these:

1. No one knows how the solar system originated.
2. It is doubtful if life can exist on any other planet.
3. Gravitation is one important factor in causing tides.

4. Our sun belongs to a galaxy of billions of stars which includes the Milky Way.

5. There are perhaps millions of other similar galaxies in the heavens.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × 2½.*

I. **According to the planetesimal theory:** (1) the planetoids united to form the solar system; (2) the earth was once a part of the sun; (3) another star helped separate the earth from the sun; (4) the earth was formed from matter thrown from the sun by centrifugal motion; (5) 10 planets were formed, but one exploded, leaving only 9.

II. **The following heavenly bodies belong to the solar system:** (6) all "evening stars"; (7) Arcturus; (8) meteors; (9) one sun and many moons; (10) some comets.

III. **That planet less dense, but larger than the earth, having a moon larger than our smallest planet and an atmosphere unsuited to human beings, is:** (11) Pluto; (12) Venus; (13) Neptune; (14) Jupiter; (15) Saturn.

IV. **The moon:** (16) travels around the sun once a year; (17) moves around the earth about once a month; (18) rotates on its axis once in 24 hours; (19) keeps one side always towards the sun; (20) has its surface covered with plains, rivers, seas, and mountains.

V. **Eclipses of the sun:** (21) occur once a month; (22) may be partial, total, or annular; (23) may result when the dense shadow of the moon fails to reach the earth; (24) may occur on the full of the moon; (25) cannot occur in cloudy weather.

VI. **The relation of the moon and sun to tide production is such that there is:** (26) a spring tide at the time of an eclipse of the sun; (27) a neap tide at the time of an eclipse of the moon; (28) a flood and ebb tide at a new moon; (29) a flood and an ebb tide at the first quarter; (30) a spring tide at the full of the moon.

VII. **The following heavenly bodies are self-luminous:** (31) the sun; (32) the moon; (33) the North star; (34) Venus; (35) comets.

VIII. **Our own galaxy:** (36) holds all the stars we can see without a telescope; (37) is composed largely of the Milky Way; (38) is the only galaxy in the heavens; (39) is many thousand times as large as the whole solar system; (40) rotates about a common center.

PRACTICAL PROBLEMS

1. Give an account of all the ways that man makes use of the sun and the moon and of the various activities produced on the earth by them.
2. Compare an atom of matter, the solar system, our own galaxy, and galaxies which fill space far beyond our own. Distinguish between fact, theory, and imagination which you may use.
3. Calculate roughly the time it takes light to travel from the moon to the earth.
4. Is it possible for ice to exist on the planet Mercury, which is so close to the sun?

LIBRARY RESEARCH READING

1. Look up in periodicals articles dealing with astronomy.
2. Find out the stories of Herschel and Lowell as related to the discoveries of Neptune and Pluto respectively.
3. Compare the views of Ptolemy and Copernicus regarding the structure of the universe.
4. Write up imaginary trips, as "A Visit to Saturn," "A Week under the Clouds of Venus," or "A Trip on Mars."

SCIENCE FOR LEISURE TIME

1. Find out from an almanac what eclipses are due the coming year. Plan to see one of them if it is possible.
2. Keep track of the evening and morning stars during the remainder of the school year. Find these stars in the heavens.
3. Keep a scrapbook on "Heavenly Bodies." You will find many interesting pictures, notes, and articles in the papers and the magazines that you may wish to refer to in the future. A neatly arranged scrapbook will provide you with valuable reference material for future use and enjoyment.

SCIENCE CLUB ACTIVITIES

1. **An evening with the telescope.** There are many amateur astronomers. If you cannot arrange for your club to visit a real astronomical observatory, then try to find a friendly amateur who will let you use his telescope. Choose a night when the moon is less than quarter so that its light will not dim the stars too much. You will be interested to look at some of the constellations; to find double

stars; to see the evening stars if they happen to be on parade; to see the moon, and perhaps you will be able to see the great nebula in the constellation Orion.

2. **Our science heroes.** Devote one meeting to the great scientists who have contributed to our knowledge of astronomy. Make assignments at one meeting for reports to be given at a future meeting.

3. **A moon program.** Have reports upon such topics as: Theories of the craters on the moon; Cause of the "man in the moon"; Superstitions regarding the moon; Origin of the moon.

READING REFERENCES

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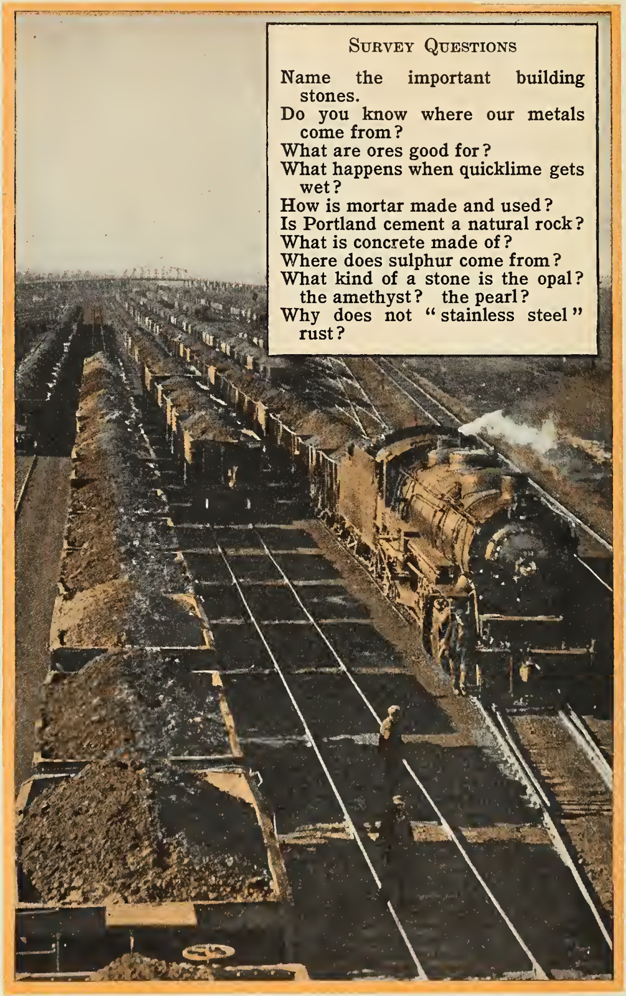


SURVEY QUESTIONS

Name the important building stones.

Do you know where our metals come from?

What are ores good for?

What happens when quicklime gets wet?

How is mortar made and used?

Is Portland cement a natural rock?

What is concrete made of?

Where does sulphur come from?

What kind of a stone is the opal? the amethyst? the pearl?

Why does not "stainless steel" rust?

Galloway

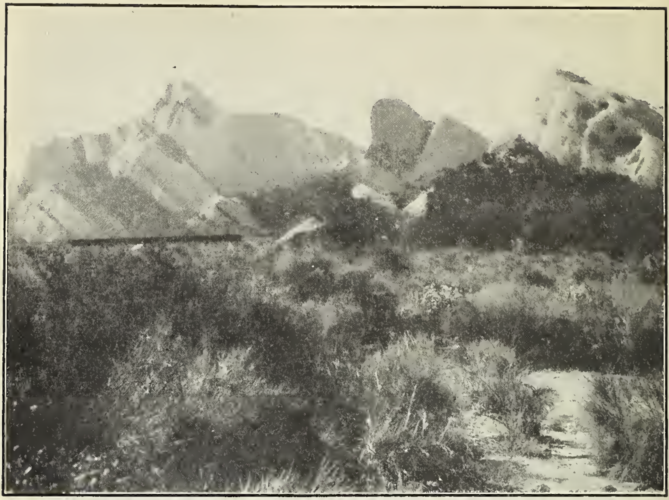
UNIT XII

THE EARTH IS A STOREHOUSE OF WEALTH

PREVIEW

Many boys and girls start a diary. For many years they keep rather imperfect records of their activities, but when they get older they have the habit of making regular entries in the diary so that the record of their doings in their more mature years is more complete than that of their younger days. So it has been with the diary which the earth has kept. There is no record of its infancy and childhood and very imperfect fossil records of its youth. But as years passed on toward maturity we find page after page giving a fairly complete story of what happened and of the kinds of life that existed. The pages of this diary are the strata of rock found in the earth and the records are the impressions made in these strata by various living creatures that lived when the material in the rock was deposited. The arrangement of strata, their relation to other kinds of rock, their position in the earth's crust, the kinds of material which has formed in them — all tell a wonderful story to the geologist to whom we go for interpretation of their meanings. But how were these rock strata formed? Geologists tell us that oceans of water made reservoirs in which deposits could accumulate. Changes within the earth have caused it to be raised and lowered at intervals so that areas that were once the bottom of oceans have become dry land, and land areas have sunk beneath the seas. It is through such changes as these that the valuable sedimentary or stratified rocks have become available to man.

Other forces have been at work as well. This old earth of ours is never very stable. Its rocks have been twisted and folded by pressure or strain of one mass of rocks against another. Even the hardest rocks behave as if they were plastic when subjected to



Wright Pierce

Along the line of the great San Andreas fault over Cajon Pass, California. Notice the railway at the foot of the tilted sandstone cliffs. Notice the layers. What does this mean? This fault extends almost the entire length of California and has been responsible for several earthquakes.

great pressure in the depths of the earth. Then volcanoes or rifts in the rocks have opened and poured out molten lava, or movement of blocks of rock along fault lines have caused earthquakes.

In addition, other changes take place. Water may wash out areas, changing their appearance and exposing rocks which have been covered, or covering rocks that have been exposed. Water may dissolve certain rocks, and after it is gone, minerals may crystallize out of the solution thus formed. Great heat within the earth may make new combinations of rocks or minerals through chemical action. These and many other happenings known to the geologist may occur and are continually making changes in the composition of the earth.

Thus we see that the forces of nature — heat, pressure, chemical action, and solution — acting upon the elements in matter within the earth's melting pot deep below the surface of the earth have created many useful materials. These materials are a source of wealth to man and have added greatly to the present-day civilization.

The scenic beauty of natural rock features, lakes and forests, and the mineral springs, hot springs, and geysers may also be considered part of the storehouse of wealth that the earth contains. The game in our forests and fish in ponds of water, which give sport and recreation to large numbers of people, may be said to be indirectly the result of the geologic formation of the rugged country where they live. The recreational opportunities offered in some of our government national parks are due to the same forces of nature which have made our earth a storehouse of wealth.

Before beginning your study of the problems which follow, let us recall some of the generalizations on which this unit is based. Here are some of them; perhaps you can add others to the list.

1. The earth is very old.
2. The earth's surface has undergone many changes.
3. The earliest rocks formed were igneous.
4. Erosive forces, both mechanical and chemical, are changing the surface of the earth today.
5. Soil is made out of rock.

PROBLEM I. HOW WERE OUR USEFUL ROCKS AND MINERALS FORMED?

Field Exercise. Collect different specimens of rock found in your community. Bring them and any other specimens of rock which you may have, to school for laboratory study. Record in your notebook where each specimen was found. If you live in a part of the country where rocks are abundant, note where they come out of the ground. Do they lie in layers? If so, look for the remains or impressions of plants and animals in them.

Laboratory Exercise. Arrange the specimens in order according to their hardness. You can determine this by scratching them with the blade of a knife, or by finding if they will scratch glass or will scratch each other.[1] Examine them with a magnifying glass. Describe them.

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[1] TABLE OF HARDNESS

1. Talc — easily scratched by fingernail. 2. Gypsum — scratched by fingernail, but not easily. 3. Calcite — scratched easily with knife point, but not with fingernail. 4. Fluorite — scratched with knife, but not easily. Does not scratch glass. 5. Apatite — scratched with knife. Scratches

Are they made up of small grains? Are the particles large or small? Have they rounded or sharp edges? Do you find any crystals (definitely shaped particles) in them? Are the particles all the same size in the different rocks? In which of the three classifications of rocks which follow will you place your specimens?

Three Groups of Rocks. You doubtless recall that there are three important groups of rocks. The oldest were once molten and because of their origin are called *igneous* rocks. Another kind were laid down under water by deposit of materials and are called *sedimentary*. A third group were formed from either of the above by changes of pressure and heat so that they became soft and pliable. This allowed them to be twisted into many irregularly banded shapes and forms. These rocks are called *metamorphic*.

Heat and Rock Formation. In some of the processes of mountain formation, breaks occurred which allowed liquid rock to rise and form huge beds near the surface. Here it solidified after cooling. Lava and granite are examples of such rocks. The

A recent lava flow in the Mohave Desert. Recent means from 5000 to 10,000 years ago. Are there any volcanoes still active in the United States?

glass with difficulty. 6. Feldspar — will scratch glass easily. Can be scratched with knife with difficulty. 7. Quartz — will scratch glass easily. Cannot be scratched with knife. 8. Topaz — harder than quartz. Is scratched by corundum and diamond. 9. Corundum — harder than topaz. Is scratched by diamond. 10. Diamond — hardest mineral. Is scratched by none, but will scratch all others.

value of much of our granite is due to the even texture and fine mineral formation that has resulted in this way. Limestone, buried so deep that heat has acted upon it, has been changed to metamorphic marble and thus has had its value greatly increased. Sometimes the heat was so great that a flow structure resulted with layers of varying color. This increased its beauty and usefulness for many purposes.

Heat and Ore Formation. The great heat present deep within the earth has been a great factor in the formation of metal-bearing ores. The heat sufficient to form metamorphic rock has produced vapors containing minerals, many of them oxides or sulphides of metals. These have been deposited in cooler surrounding rock into which they have been forced under pressure. Iron, copper, zinc, and lead ores are frequently found along lines where different masses of metamorphic rock meet. The veins and fissures formed when large masses of rock cooled and contracted often become filled with hot watery solutions of minerals which later crystallize. This is the way veins of minerals are formed.

Wright Pierce

Two types of mines. What geological action has made necessary these two ways of getting ore?

Ores Formed by Oxidation and Weathering. Some ores have been formed by weathering and oxidation. It is estimated that iron makes up 5 per cent of the earth's crust. But although there is so much of it, there are few places where it is found in sufficient quantities to make it profitable to mine. In such places a part of the rock containing the ores was eroded or weathered, resulting in accumulation of iron ore which can easily be mined. The iron ore deposits in Minnesota and areas bordering the Great Lakes, which supply about 85 per cent of the iron used in the United States, have been concentrated in this way.

Valuable Crystals. Crystals are formed from water solution and from the cooling of a molten mass. Many minerals, as feldspar, calcite, quartz, garnet, hematite, sulphur, and many others, are formed as crystals. A few of these minerals form our precious and semiprecious stones, such as beryl, which gives us our emeralds and aquamarines; corundum, which gives us rubies, sapphires, and amethyst, opals, quartz, topaz, and the diamond, which is our hardest known substance.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

altered
cooled
land
pressure
dirt
weathering
color
precious
heated
veins
worthless
once
crystals
water
cracks
solid
texture
molten
half
semi
oxidation
original
formed

Rocks are classified into igneous or those which were (1)____ in a (2)____ state; sedimentary or those (3)____ under (4)____, and metamorphic rocks which have been (5)____ from their (6)____ state. The internal heat of the earth has been responsible not only for (7)____ and (8)____ of our rocks, but also for the formation of (9)____, of minerals and (10)____ (11)____ stones. Ores are also collected in areas by (12)____ and (13)____. Our precious and semiprecious stones were formed from material in (14)____ solutions, which, when they (15)____ formed (16)____.

PROBLEM TEST

Suppose you had an unknown rock and you wished to classify it as well as you could with such simple means as given in the problem. Which of the following things would you do, and why?

Things to Do

1. I would compare it in color with some other rocks.
2. I would test it with acid.
3. I would scratch it with my knife.
4. I would look for crystals in it.
5. I would first decide in which group of rocks it was formed.

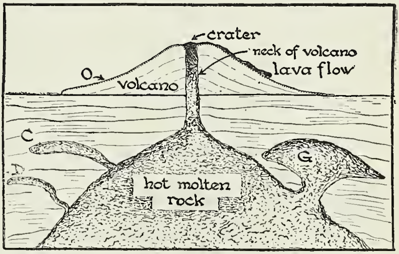
Reasons for Doing Them

1. The crystalline structure would show it to be a mineral formed from solution.
2. The scale of hardness will help to classify the mineral.
3. The three groups of rocks are igneous, sedimentary, and metamorphic.
4. Limestone dissolves in acid, granite does not.
5. Different rocks and minerals have different colors.

PROBLEM II. WHAT IS THE STORY OF GRANITE?

In many parts of the world today we find level plains or gently rolling fertile farm land. The soil in such a region will be found to be formed from rocks that were once under water. But if we travel into the rough mountains of the Far West, or the wooded ranges of the Appalachians, we find there that the rocks are mostly igneous, and that granite is found almost everywhere. It is one of the most common as well as the most useful of the igneous rocks.

The Texture of Granite. The size of crystals of the minerals which compose a rock tell a little of its past history. If the same material which makes granite were poured out of a volcano in liquid form, it would cool and solidify so rapidly that crystals even of microscopic size could not form. It would appear to be a glassy rock without crystalline structure.



How igneous rocks were formed. When the molten rock poured out through the crater of the volcano it was lava, but at *C*, *D*, and *G*, confined under the pressure of the layers above it, became granite or other igneous rocks.

If it cools slowly under a deep blanket of other rock and soil, crystals of various minerals may develop. The slower the cooling, the coarser will be the crystals. Granite is an example of crystalline igneous rock. All granite contains both quartz and feldspar, and most granites have in addition either mica or hornblende. The quartz is silica (SiO_2) and is the hardest and most durable of the minerals in granite.

Demonstration 1. Minerals.

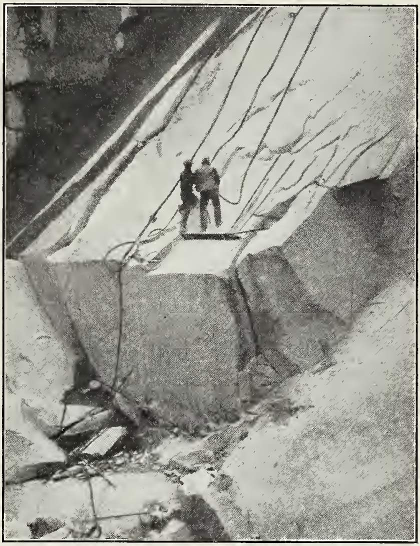
Bring to class specimens of quartz, feldspar, mica, and hornblende. What are the characteristic appearance and the relative hardness of each?

Durability of Granite. The superiority of granite over other building stones is due to its greater resistance to weathering. The great beauty of polished granite adds to its value. It is often used as a facing for buildings, being backed up by cheaper stone. It is our hardest and most durable building stone. It is much used for monuments, and poorer grades were once much used as paving blocks. The life of a building stone is the length of time before it shows signs of crumbling or chipping. Compare the life of various building stones as given in the following table.

STONE	LIFE IN YEARS
Micaceous limestone	2 to 15
Micaceous brownstone (sandstone)	15 to 30
Compact brownstone (sandstone)	15 to 30
Marble	40 to 80
Fine marble	50 to 100
Granite	57 to 200

The Minerals in Granite. Sometimes the molten mass of rock has been so deep below the surface of the earth that the cooling has been unusually slow. This has given the individual minerals more chance to form. As a result we have almost complete separation of the different minerals. There will be large masses of feldspar, or quartz, and enormous crystals of mica. This stone is not good for building purposes, but it is mined to get the large clear sheets of mica for stove windows and electrical insulation. It is mined, too, for the feldspar which is ground to a fine powder to be used in the finer grades of pottery. The quartz, if clear, may be used for semiprecious gems and for making quartz glass in the electric furnace.

Granite Quarries. If you visit a quarry, you will see that men are able to cut out blocks of granite with apparent ease, even though you can see no cracks or cleavage lines to help them. When the granite was formed it was under great pressure. The amount of pressure was greater in one direction than in another. As the liquid mass cooled, the mica and feldspar crystallized out before the quartz and the crystals formed with their largest faces at right angles to the direction of the greatest pressure. Granite splits easily in this plane, technically called the *rift*. At right angles to the rift we have the *grain* along which the granite splits second in ease. These factors of rift and grain are of much economic importance since they make quarrying easier.



Keystone View

A granite quarry. Can you find the *rift* and the *grain* in this rock?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

sedimentary
volcanic
stratified
metamorphic
floated
brittleness
rift
minerals
rate
mined
pottery
extensive

slowly
grains
grain
durability
beauty
scope
grained
texture
cleavage
rapidly
igneous
rapid
windows
crystals
insulation
granite

An (1)____ rock containing at least two different kinds of crystalline (2)____ is (3)____. The (4)____ of granite depends upon its (5)____ of cooling. When crystals form (6)____ they are large. Fine (7)____ granite is the result of (8)____ cooling. Because of the (9)____ of granite and its great (10)____ when polished, it has (11)____ use. Exceedingly slow cooling may produce such large (12)____ of minerals that they are (13)____ for their own individual use; as mica for (14)____ and stove (15)____, and feldspar for making (16)____. The plane in which granite splits most easily is the (17)____ and the plane of next easy splitting is the (18)____.

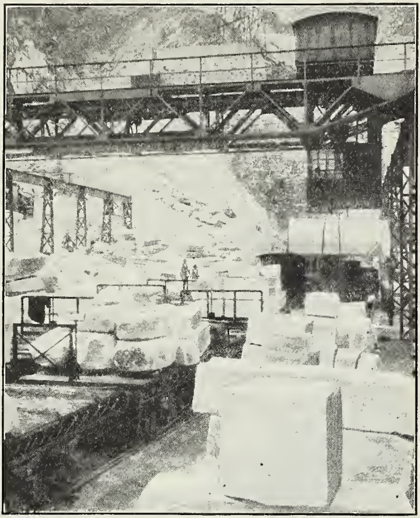
PROBLEM TEST

By some accident in the printing room, some words have become misplaced in the following paragraph. Try to tell how they were originally placed before the accident happened. Write the words as you think they should go, making the list in numerical order.

Our (1) *beautiful* building stone often used for (2) *pottery* is (3) *sandstone.* It is (4) *fine,* compact, and resists weathering. It belongs to the (5) *sedimentary* group of rocks. Granite is (6) *less* durable than (7) *feldspar* or (8) *sand,* which are (9) *common* rocks. (10) *Mica* is sometimes found in (11) *igneous* crystals, but more often as a massive crystalline rock and is used in making quartz glass. (12) *Quartz* is ground to a powder for making (13) *hardest* (14) *monuments.* When igneous rock weathers, it produces (15) *silica.* The (16) *more* durable minerals, feldspar and mica, wear away, leaving (17) *granite.*

PROBLEM III. WHAT INDUSTRIES DEPEND UPON LIMESTONE?

Origin of Limestone. There are in the ocean millions upon millions of tiny animals which form a limestone shell from the chemicals held in solution in the sea water. Some we can see but many are of microscopic size. In Florida a substance known as *coquina* is formed from masses of small shells partially cemented together. If these shells were buried deeply below many heavy layers of sediments, they would be squeezed together and produce the more common form of limestone. Over a long period of time accumulations of microscopic shells on the ocean floor produce deep beds of limestone shells. With suitable covering, pressure, and heat these eventually are consolidated into limestone rock. If at some future time that part of the ocean bed is raised to become a part of land, the limestone rock becomes available to man. The chalk cliffs of England and France and some of our own finer limestones were made in this manner.



© *Burton Holmes, Ewing Galloway*

The famous marble quarry at Carrara, Italy. What difference is there between pure limestone and marble?

What Is Limestone? As a chemical, limestone is calcium carbonate, but there are many impurities mixed with the carbonate. Pure calcium carbonate is white, but limestone is usually gray. Some marble is very pure calcium carbonate and therefore white in color. Marble is a metamorphic rock formed from limestone which has been heated and changed to a crystalline structure. Both marble and limestone have the same characteristic reaction to an acid and both show calcium in a flame test.

Demonstration 2. Characteristics of Limestone.

Test samples of limestone and marble.

1. *Acid Test.* Put a drop of concentrated hydrochloric acid upon a surface of limestone; of marble. What causes the effervescence?

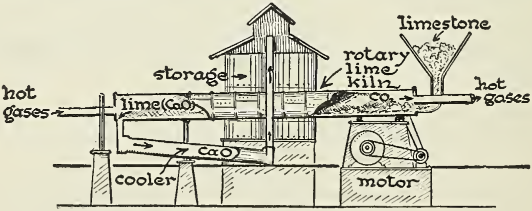
2. *Flame Test.* Powder a little limestone. Test a platinum wire in a colorless flame. It should give no color. Wet it in distilled water and lay it in the powdered limestone. Hold this in the flame. What is the color? Clean the wire and make a flame test of the marble in the same way. Result?

Conclusions: All limestones and marbles liberate carbon dioxide when tested with an acid. The bubbling of the gas through the acid produces effervescence. In the flame test a reddish color indicates the presence of calcium.

Limestone a Building Stone. Although limestone is softer than granite and is not as durable, yet it finds extensive use as a building stone. Because it is softer it can be sawed into blocks, making the expense of labor much less. It is more easily chiseled and hence suitable for making statues and monuments. The carbon dioxide in rain water slowly dissolves limestone exposed to the weather and its yielding to mechanical wear makes it unsuited to thresholds, stairs, and floors where there is much traffic. Marbles which owe much of their beauty to natural designs and colors are used in many interiors for pillars, stair casings, walls, and floors.

A Source of Lime. In the building trades much lime is used for making plaster for walls, for making mortar to bind brick together, and for whitewash. Limestone is the source of most of this lime. In some of the southern states a small amount of lime is made from limestone shells.

How Lime Is Made. Lime is made in a sort of furnace called a lime kiln. Limestone is broken into irregular pieces averaging a few inches in diameter and is heated to a very high temperature in the kilns. In modern kilns coal is burned in a side chamber and just the hot gases pass over the charge of limestone. In some kilns gas is used as the fuel. The charge of limestone is fed in at the top of the kiln and removed from the bottom. Calcium carbonate ($CaCO_3$), which is the chemical name of limestone, is composed of calcium, carbon, and oxygen. The intense heat



Read your text and then tell how lime is made.

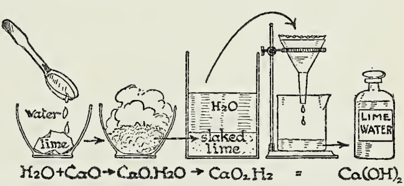
drives the gas carbon dioxide (CO_2) off and leaves CaO, which is lime. The chemist expresses this change thus:

$$\underset{\substack{\text{calcium}\\\text{carbonate}}}{CaCO_3} + \text{Heat} \longrightarrow \underset{\substack{\text{carbon}\\\text{dioxide}}}{CO_2} + \underset{\substack{\text{calcium}\\\text{oxide}\\\text{(lime)}}}{CaO}$$

As soon as the lime is made it is barreled to protect it from change in moist air because it has great attraction for water.

Demonstration 3. Slaking Lime.

Secure a lump of fresh lime about the size of your fist. Place this in a quart bowl. Pour water — a tablespoonful at a time — upon it every half minute until there is evidence of chemical action between them. Describe change in appearance. What evidence of energy is produced?


water
lime
H_2O
slaked lime
LIME WATER
$H_2O + CaO \rightarrow CaO.H_2O \rightarrow CaO_2.H_2 = Ca(OH)_2$

If a small quantity of water is used, a dry white powder will result. With more water a pasty mass is formed. A saturated solution of the product is called limewater. Lime is CaO and water is H_2O. Limewater is $CaO \cdot H_2O$ or, as it is commonly written, CaO_2H_2. This solution is the limewater that is purchased at the drug store sometimes to add to the baby's milk. The pasty mass is slaked lime. This is mixed with sand for mortar and with sand and hair for wall plaster.

Other Uses of Limestone. We have just seen one important use of lime. There are many other uses of limestone in important industries. In glass making it enters into chemical action with other compounds and the calcium becomes a constituent of the glass. In the cement industry it finds extensive use as one of the chief raw materials. In the process of removing iron from its ores it is very helpful in combining with the impurities which are almost always mixed with the ore. This makes the separation of the iron easier. Ground to a powder it is added to sour soils to sweeten them.

What Is a Pearl? Real pearls are chiefly composed of calcium carbonate. It is the same substance as the inside shell surface of the oyster. If some foreign material gets between the shell and the part of the oyster that forms the shell, it causes an irritation.

The oyster then proceeds to cover the irritating substance with a beautiful pearly form of calcium carbonate. This form unlike that in the outer shell is called *aragonite.* After a layer of this is formed, a tough organic substance is placed over it. These layers are very thin and they are added alternately, building up the pearl to considerable size. The pearl then is made of concentric layers of aragonite and this organic substance. It is due to these thin layers and their action on light rays that the pearl produces such luster and iridescence.

The Cement Industry. Artificial stone is rather rapidly replacing the natural building stone. Houses, skyscrapers, bridges, dams, road surfaces, and hundreds of other smaller things are today using many millions of tons of cement, so that someone has called it the "New Stone Age." Lime is one of the raw materials that is needed in making Portland cement. When Portland cement is mixed with water, sand, and broken stone or pebbles in the right amounts, concrete is produced. The rock produced is

A modern concrete war memorial. Of what practical as well as artistic value are such bridges?

so strong that, when broken, it will break through the pebbles held within rather than separate at their surface.

Demonstration 4. To Make Concrete of Various Mixtures and to Compare Their Properties.

Materials: Portland cement. Sand. Steel knitting needles. Frame with six compartments, each about 1½ inches deep, 1 inch wide, and 10 inches long. Mix sand and cement dry, in proportions indicated. Then add water to make a pasty mass which slides easily from the trowel. Make the following mixtures and pour them into the frames:

TEST	CEMENT	SAND
1.	All cement	0
2.	1 part cement	2 parts
3.	1 part cement	4 parts
4.	1 part cement	6 parts
5.[1]	1 part cement	5 parts
6.[2]	1 part cement	6 parts

Let the mixtures harden from three to four weeks. Examine for appearance. Test for strength. If supported at the ends, how much weight across can be supported? Conclusions?

In concrete construction of buildings, the mixture of cement, sand, gravel or pebbles, and water is poured from mixers into wooden frames which are later taken off after the mass hardens. Much concrete construction today is made around steel rods which give greater strength to the mass. This is known as *reinforced concrete.*

Raw Materials for Cement. Portland cement requires approximately this composition:

Calcium carbonate	75%
Silica (SiO_2), alumina (Al_2O_3), and iron oxide . .	20%

There is on an average about 5 per cent of impurities which do no particular good or harm. There are some natural rocks found in the Lehigh Valley in Pennsylvania that are called *cement rocks* which have this composition, and so cement can be made directly from that one raw material. In most cases other raw materials must be mixed, for example, limestone and clay; limestone and shale; limestone and blast-furnace slag; or limestone and marl or clay. These combinations are used where found locally. Almost every state in the union has a supply of rock materials from which cement is manufactured.

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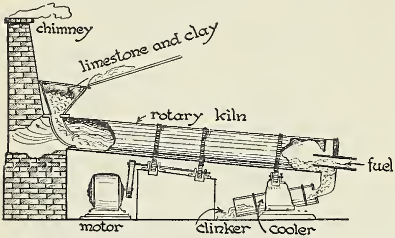
[1] Reinforce by putting in five steel knitting needles well spaced.

[2] Instead of using sand use dark earth or loam.

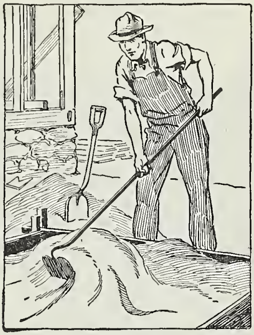
Cement Manufacture. Cement making is a machine job. Practically everything is done mechanically. In the dry process of manufacturing Portland cement, the raw materials are crushed and ground in ball mills until it is so fine that at least 85 per cent of the powder will pass through a 200-mesh sieve. So small are the particles of cement that it would take 40,000 to make a single layer one square inch in area. It is then burned at a temperature ranging from 2500° F. to 3000° F. to make a clinker, and the clinker then is ground to a powder again. The powder is then bagged and kept dry until used. As a rule powdered coal is used to supply the heat used in this industry. A comparatively few plants use oil or gas. In 1880 only 8000 tons of cement were manufactured in the United States but within recent years more than 30,000,000 tons a year have been produced.



Read your text and explain how the rotary kiln works.

The uses of cement are much greater than formerly. Cement roads have been found to be the most durable ones that can be made. About 32.5 per cent of cement manufactured in 1928 was used for paving, 25 per cent for public and commercial buildings, while the rest was used for building small homes, bridges, dams, railway work, irrigation ditches, farm buildings, and sidewalks.

Plaster, Mortar, and Stucco. No modern house could be well constructed without having mortar, brick, hollow tile, or plaster to cover the inside walls. All of these materials contain lime or are held together by lime worked into mortar. In making mortar or plaster, water is poured upon the lime and combines with it. Chemical action takes place, as we can see by the steam which rises. The product is called "slaked lime." This is mixed with the sand to form mortar. Plaster is simply mortar with hair or other fibrous substances added to help hold the material together. Stucco is a fine plaster (often colored) which is used over wire or other things such as wood lathing. Slaked lime in mortar or plaster absorbs carbon dioxide from the air and produces calcium carbonate, which accounts for its hardening.


What process is taking place here?

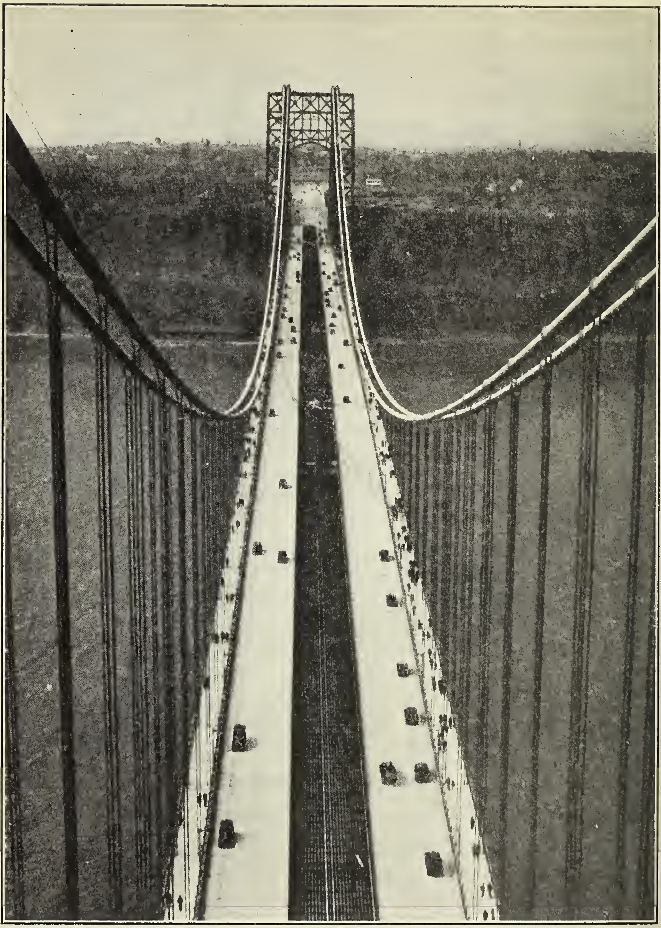
An exterior stucco used in a similar way is made from cement. It makes a warm, waterproof, and firm, durable coat, and it is much used in small homes because of its cheapness and the ease with which it is applied.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

artificial
neutralize
concrete
unnatural
sweet
sour
clay
sand
dioxide
stone
natural
neutral
lime
made
carbonate
hydroxide
cement
more
water
sandstone
limestone
given
less
stones

Limestone is one of the common (1)____ building (2)____. It is (3)____ durable than granite. Lime is (4)____ by heating (5)____ until carbon (6)____ is (7)____ off. Lime when mixed with (8)____ gives off heat and produces slaked (9)____. Lime, limestone, and the base calcium (10)____, have the power to (11)____ an acid and may be used on a (12)____ soil for this purpose. One of our large industries, the (13)____ industry, makes use of much lime. Cement, water, (14)____, and pebbles are mixed to produce (15)____, which is frequently stronger than (16)____ stone.



Galloway

The **3500**-foot span of the George Washington Bridge is at present the longest in the world. The four great cables which support the span are three feet in diameter and each is made up of **26,474** steel wires. Where else is steel used in this construction?

PROBLEM TEST

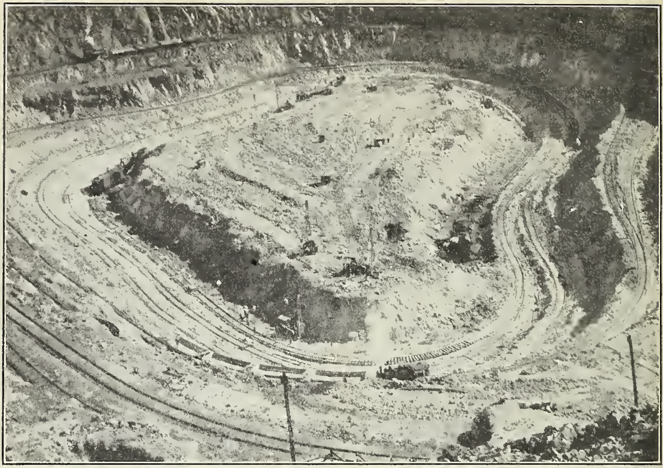
By some accident in the printing room, some words have become misplaced in the following paragraph. Try to tell how they were originally placed before the accident happened. Write the words as you think they should go, making the list in numerical order.

Since (1) *lime* is softer than (2) *iron,* it is more easily cut into blocks. Marble is (3) *igneous* rock, but this does not mean it is as hard as (4) *common* rock. A (5) *hard* product of the (6) *much-used* limestone is (7) *clay.* (8) *Hot* temperature is required to make this. (9) *Portland* lime will combine with (10) *fresh* water and produce a (11) *slaked* pasty mass of (12) *raw* lime. (13) *Metamorphic* cement, window glass, smelting (14) *granite,* and agriculture take large quantities of (15) *cement* and limestone. Limestone and (16) *lime* are two (17) *cold* materials used for cement. A (18) *high,* durable (19) *limestone* is made from sand, water, gravel, and (20) *concrete.*

PROBLEM IV. WHAT METALS HAS MAN FOUND MOST USEFUL?

We Live in an Age of Steel. One of the greatest discoveries made in the ages before the days of science was that of producing iron by heating a rusty-looking earth. This accidental discovery made by some aboriginal savage started the Age of Iron many thousands of years ago. An improvement on iron — steel — dates back to 1855, when Bessemer showed how to produce steel from iron quickly and cheaply. We are now in the Age of Steel. The methods of producing iron and steel have already been discussed in a previous unit. (See pages 152–153.)

The Importance of Copper. We might almost call this an Age of Copper as well as an Age of Steel. Copper has come to be so closely interwoven with our everyday life. In the city of New York alone 5,000,000 miles of copper wire are required to give people the privilege of telephone communication. The Southern California Edison Company delivers electric power over a high tension transmission system in which they use 10,000,000 pounds of copper. The average automobile carries around nearly 50 pounds of copper. Next to iron copper is the most common metal. There are many compounds of copper found in nature as well as some free or native copper.

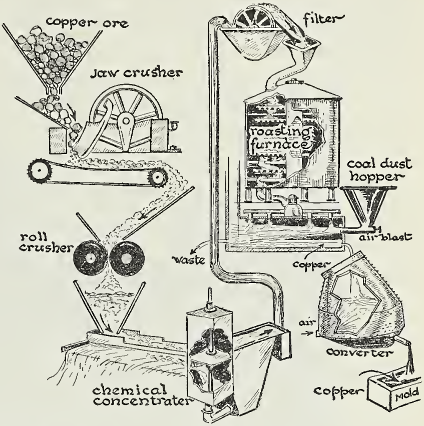


Galloway

An open pit copper mine at Brigham, Utah. What advantage has the open pit mine over the shaft?

How Copper Is Smelted. If you have ever traveled in the West, you may have seen one of the large smelters, with the tall chimney used to carry off the poisonous fumes generated in the complicated process by means of which copper is separated from the ore. There are two steps in this process. First, the ore is crushed and the copper "concentrated" by chemical means. Then the concentrate passes to a roasting furnace where it is freed from most of its sulphur. Then the impure copper passes into a converter where it passes through a process similar to that which changes iron into steel. At the end of this process it comes out as commercial copper. The purest copper is produced by a process of copper plating. This is called *electrolytic refining.* A current of electricity is passed through a solution of a copper salt in which the anode is a bar of impure copper. Pure copper is deposited upon the negative electrode while the impurities drop to the bottom of the bath.

Its early use was in the preparation of bronze, an alloy of copper and tin, which is about 10 per cent stronger than copper alone. The metal mirrors of the old Roman days were of bronze. Another important alloy of copper, called brass, is made from mixing copper and zinc. Varying amounts of zinc are used up to 50 per cent which gives a whitish brass. With less zinc the color is yellowish. With zinc and nickel, copper makes an alloy called German silver which has been used as a substitute for silver articles because of its resemblance to silver.



Follow the process of converting copper ore into copper. Which processes are mechanical and which chemical? Where is water used? Where heat?

One of the greatest uses of copper is for conducting electricity. The copper must be very pure for this purpose. The electrical conductivity drops 20 per cent if as much as .05 per cent of carbon is present and drops 80 per cent if .9 per cent of phosphorus is present.

Lead Is a Common but Useful Metal. Iron is distinguished as the structural metal, copper as the metal of communication, but lead is just an ordinary good all-around metal that gives plenty of everyday inconspicuous service. Name a few uses. Next to iron, lead is the cheapest metal. The earth supplies an abundance of lead ore called galena. This is a compound of lead and sulphur.

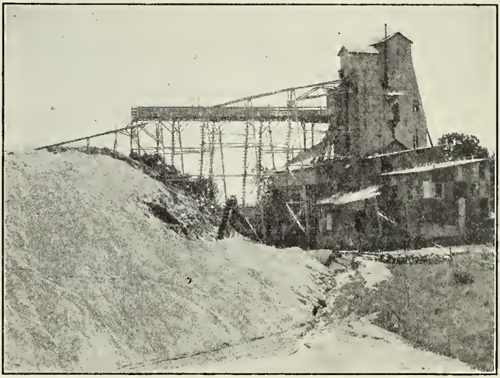
Demonstration 5. Production of Metallic Lead.

Make a half-inch hole in a block of charcoal. Fill this with red lead. Close the air holes of a Bunsen burner. Turn the gas down to a flame half an inch high. With a blowpipe direct a reducing flame upon the red lead. Keep it continuously hot until the little "bubbles" of lead that appear are united into one globule of bright metallic lead.

$$\underset{\text{Red lead}}{Pb_3O_4} + \left\{\begin{matrix} 2H_2 \\ C \end{matrix}\right\} \begin{matrix} \longrightarrow \\ \longrightarrow \end{matrix} \left\{\begin{matrix} 2H_2O \\ CO_2 \end{matrix}\right\} + \underset{\text{Lead}}{3Pb}$$

The carbon of the charcoal, the hydrogen, and other components of the gas combine with and remove the oxygen from the red lead, leaving just the pure metal.

How Lead Is Extracted. In the process of extracting lead, the ore is roasted to produce a lead oxide which is then reduced to pure lead by heating with more lead sulphide ore or with coke. The reduction of the oxide with carbon is easily illustrated by heating an oxide of lead in a reducing flame on charcoal. A reducing flame is that part of the gas flame where the hot gases are ready to take on oxygen but where little oxygen is available. This is in contrast to the tip of the flame where the body heated can easily get oxygen from the surrounding air.



Galloway

A lead and zinc mine in Wisconsin. Lead is often found associated with other metals, especially silver and copper. Why do we have the mound at the left? Where is the mine shaft?

Some Common Uses of Lead. The ease of melting and working lead has made it a popular metal from very early times. You will find lead pipes used in Roman times in the plumbing of those days and in our modern houses, in flashings where the chimney comes through the roof, and in lining tanks and sinks and various other industrial uses. Most storage batteries used in automobiles have plates made of lead. Lead shot and rifle balls aid the hunter, and lead weights make vertical lines for surveyors. Solder is made by mixing lead and tin, the most common mixture being the

50–50, or equal parts. It is interesting that while lead has a melting point of 620° F. and tin 450° F., the resulting solder melts at a lower temperature than either one, 358° F. Lead and antimony are used in type metal. Lead compounds are of much importance, particularly in paints. Red lead is a compound of lead useful in making tight joints in plumbing and in painting iron surfaces. White lead paint (lead carbonate) is used more than any other. It is the base for adding pigments for other colors. Tetraethyl lead, added in small quantities to gasoline, produces an "anti-knock" gasoline.

Zinc and Tin as Protectors. A very important use of these metals is to protect iron. Iron quickly rusts away in air, but zinc and tin are not corroded by the air. Iron vessels coated with a very thin layer of zinc will resist weathering and wear far longer than iron alone. Iron treated with zinc is *galvanized iron.* Much iron is galvanized for use in wire fences, screens, and especially for articles to be used near salt water.

The tin plate used in making tin cans, kitchen dishes, and covering roofs is made by dipping clean sheet iron into molten tin. When withdrawn, a protective coating of tin adheres to the iron. If this is then put under high pressure by rolling while hot, a superior quality of tin results. Ordinary tin foil is, in its best grades, nearly pure tin, but the cheaper foil contains considerable lead. Pewter is lead and tin with a little antimony which gives it hardness.

Aluminum. Bauxite is the chief commercial source of the metal aluminum, which is also found in clay, slate, feldspar, mica, and corundum.

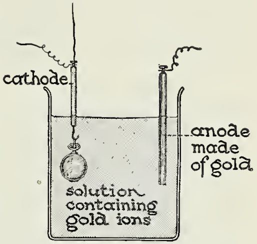
A bauxite open pit mine. What is bauxite used for?

In spite of the abundance of aluminum compounds in nature — about $7\frac{1}{2}$ per cent of the earth's crust — aluminum had never been produced commercially until in 1886 Hall found a method of extracting it from its compounds by electrolysis. In a short time aluminum was changed from a rare, expensive metal, costing $10 a pound, to a common and much used metal at about 25¢ a pound. The advantages of aluminum in kitchen utensils is their quick conduction of heat and resistance to tarnishing. In industry its lightness is of value especially in the alloys, which are strong, non-corrosive, and light. All-aluminum railway cars and street cars are coming into use as it has been found that they save about 25 per cent of the power needed. The radio industry uses a great deal of aluminum. Much aluminum is used in alloys for automobile and airplane parts. Aluminum oxide is an important abrasive. Two of our precious stones, the ruby and sapphire, are transparent or translucent forms of aluminum oxide which are slightly colored by other oxides present.

Galloway

Aluminum bars weigh less than a third of what a similar bar of copper would weigh. Name all the things aluminum is used for.

Gold. Gold occurs both free and alloyed with other metals. Much gold is found in quartz veins. It has been in use many thousands of years as shown by objects taken from ancient Egyptian tombs. Old Croesus of Lydia as early as 550 B.C. made gold the standard of coinage. When the United States used gold coins, they were 90 per cent gold and 10 per cent copper. Gold is hammered into foil $\frac{1}{1500}$ the thickness of a sheet of paper. This gold leaf is used in sign lettering, edging books, gold printing, and gilding domes of capitol buildings. A very thin coating of gold may be given to an object by the process of gold plating. An object made of pure gold is 24 carats. If a ring is marked 14 carats, it means it is $\frac{14}{24}$ gold and $\frac{10}{24}$ is some other metal alloyed with the gold. Yellow or white gold results from a mixture of gold and silver, yellow if mostly gold and white if mostly silver. Green gold is a mixture of copper, silver, and gold. Iron gives gold a bluish color. Reddish gold is formed from copper and gold.



Do some outside reading and see if you can explain this diagram.

Other Metals. Platinum is of much value in the science laboratory, because it stands high heat and does not react readily with most chemicals. It is also used for jewelry. Silver as you know is much used in jewelry, coinage, and for household tableware. Many cheaper metals are plated with silver or nickel because these metals take a higher polish and are more resistant to changes. Recently a process has been perfected by which chromium can be used in electroplating. Because of the brilliant white luster and resistance to tarnishing, chromium is very popular. It is harder than steel and so resists scratching better than silver or nickel plate. It is much used in plating automobile parts and is finding considerable use in replacing silver for household objects. Another air-resisting and acid-resisting alloy is monel metal, which is composed chiefly of nickel and copper. These two metals fortunately are found associated with each other in some ores in nature in the right proportions so that they do not have to be separated from each other to make monel metal.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

zinc
copper
aluminum
gold
chromium
platinum
iron
lead
tin
nickel
kerosene
gasoline
benzine
ethyl
strength
abundance
roasting
lightness
common
electrolytic
separated
pure
cheapest
reducing

Iron is our most (1)____ metal and the (2)____ as well. Copper is (3)____ from its ores by (4)____ and then (5)____. If it needs to be very (6)____, it is refined by an (7)____ process. The metal present in a common "anti-knock" (8)____ is (9)____. Galvanized iron is iron coated with (10)____, while a piece of (11)____ coated with tin is called just (12)____. The metal obtained from bauxite is (13)____, which owes its great popularity to its (14)____, (15)____, and resistance to tarnishing. The brilliant white lustrous metal which can now be coated upon other metals by electrolysis is (16)____.

PROBLEM TEST

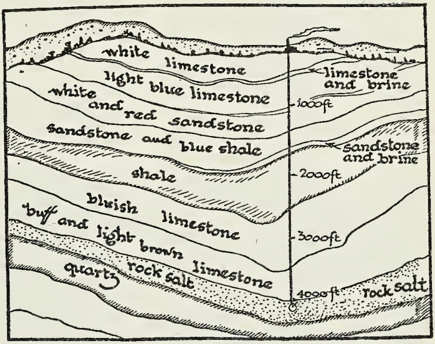
By some accident in the printing room, some words have become misplaced in the following paragraph. Try to tell how they were originally placed before the accident happened. Write the words as you think they should go, making the list in numerical order.

In the (1) *old* process of refining (2) *lead*, (3) *bright* copper is deposited on the (4) *impure* electrode and at the same time copper leaves the (5) *soft* bar which is the (6) *negative* electrode. The (7) *galvanized* metal, (8) *solder*, is easily rolled into large flat (9) *boats* which find abundant uses. (10) *Pure* iron is better for use in salt water (11) *tin* than ungalvanized (12) *copper* because the coating of (13) *sheets* keep the iron from rusting. Lead and (14) *zinc* make (15) *bauxite* but by adding antimony, (16) *iron*, much used in the (17) *dull* days, results. (18) *Modern* aluminum metal comes from a (19) *positive* white rock called (20) *pewter*.

PROBLEM V. WHAT IMPORTANT NON-METALS COME FROM THE EARTH?

The Value of Common Salt. History does not go back to the time when salt was not considered a necessity of life. There was a famous military road, Via Salaria, meaning Salt Road, which was built to transport salt from salt works on the Mediterranean Sea to Rome. Caesar paid his soldiers partly in salt. This was called in Latin "salarium" and translated is "salary." So you see why when anyone says that man is not "worth his salt," he really means he is not worth his pay. The reason for the importance of salt to man lies in the fact that it is one of the essential constituents of the human blood so man cannot get along without it. It is believed there could never have been any animal life such as we know on the earth if there had not been common salt.

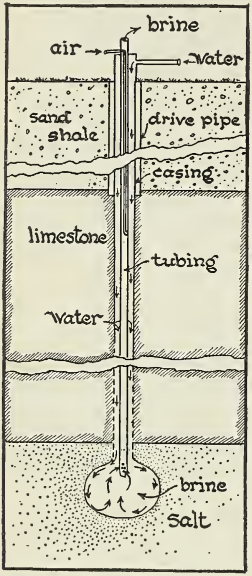
Where Salt Comes From. The early settlers in America got salt from the ocean, using the sun's heat to evaporate the water. Salt deposits have been discovered deep in the ground near Syracuse, N. Y. Here they dug the salt out just about as they mine coal. For many years these mines supplied the demands of the greater part of the country. At present Michigan is an important center of salt production.


white limestone
light blue limestone
white and red sandstone
sandstone and blue shale
shale
bluish limestone
buff and light brown limestone
quartz rock salt
limestone and brine
1000ft
sandstone and brine
2000ft
3000ft
4000ft
rock salt

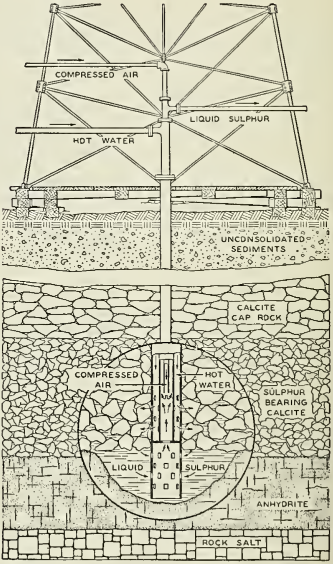
A cross section of the earth's surface showing salt deposits. Read your text and explain how they got there.

How did these great storehouses of salt get into the earth? Probably long ages ago there were inland salt seas which dried up and the salt crystallized in deep layers covering what had been the bottoms of the seas. Later water brought in sediments of one kind at one period and another kind at another period until the salt was buried thousands of feet below the earth's surface. If the oceans were to dry up, mathematicians have calculated that it would give us $4\frac{1}{2}$ million cubic miles of rock salt. This is more than the volume of land above sea level on the entire earth. So it would seem there is no danger of the salt supply giving out as our coal and oil supplies are likely to do.

Salt Wells. A common method of mining salt today is to bore a well down into the salt layer. A brine pump is set down into this. The well has a casing. The brine pump has a double pipe running all the way down, making two concentric chambers. A small air pipe goes down inside the inner pipe nearly to the bottom. Pure water dissolves the salt forming brine. The brine rises in the inner pipe. A current of compressed air in the air pipe, which is bent upward at its lower end, gives upward force to the brine.


brine
air
water
sand
shale
drive pipe
casing
limestone
tubing
water
brine
salt

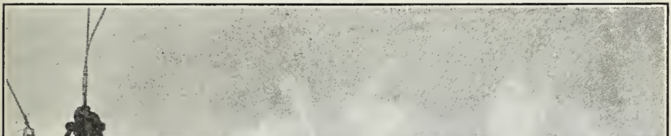
Explain how salt is obtained commercially from great depths.


COMPRESSED AIR
LIQUID SULPHUR
HOT WATER
UNCONSOLIDATED SEDIMENTS
CALCITE CAP ROCK
COMPRESSED AIR
HOT WATER
SULPHUR BEARING CALCITE
LIQUID
SULPHUR
ANHYDRITE
ROCK SALT

Explain this diagram after reading your text.

Sulphur. One of the most important nonmetallic elements found in the earth's crust is sulphur. It is the raw material for making sulphuric acid and sulphurous acid, both of which have extensive industrial uses. Sixty years ago we depended upon sulphur imported from Sicily. Rather recently beds of sulphur a thousand feet below the surface were discovered in Louisiana. It was many years before science engineering was able to devise a successful commercial process for getting the sulphur out at a profit. The process is as follows. A boring is made such as is used in drilling for oil. Three concentric pipes are run down in this to the sulphur deposit. Water heated under pressure to above 300° F. is forced down the outer pipe and after it has had time to melt the sulphur (melting point 248° F.), compressed air is sent down through the inner pipe. Liquid sulphur is forced out through the third pipe. Seventy per cent of the sulphur is used in making sulphuric acid, 18 per cent in the paper industry, 3 per cent in rubber manufacture, and small amounts for bleaching, fumigating, spraying, and in explosives.

Getting Bromine from the Ocean. You are all familiar with ethyl anti-knock gasoline, but few are aware that one of its important ingredients is a compound of the element bromine. Scientists have known for a long time that there are from 65 to 70 parts of bromine in every 1,000,000 parts of sea water, but only recently has any attempt been made to extract it. Now a plant has been built at Cape Fear, N. C., that takes some 30,000,000 gallons of sea water from the ocean every day, extracting about 15,000 pounds of bromine from it.

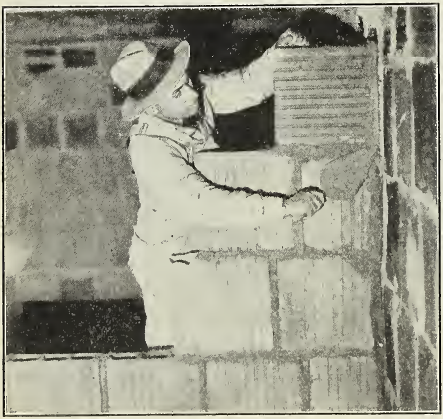


R. I. Nesmith and Associates

The intake channel at the plant on Cape Fear, where bromine is being extracted from sea water for use in ethyl gasoline.

It has been found that a very minute quantity of gold can also be extracted from the sea water as a by-product, but its cost is about 10 times the present price of gold. Some day, however, we may be able to extract this precious metal at a reasonable cost, for there is enough gold in the oceans of the world to give each one of the 2,000,000,000 people living on the earth $24,000 worth.

Silica. Silica chemically is silicon dioxide, SiO_2. Silicon and oxygen together make up nearly 75 per cent of the rock, soil, water, and living things, so you see they are very abundant. Silica, commonly known as quartz, composes a large part of sandstone, and in the sands of our beaches. Quartz is the binding material holding the minerals in granite together. In an uncrystallized form, silica is found in flint and the opal. Impurities frequently color the silica found in rock or in the form of crystals, giving us milky quartz, smoky quartz, rose quartz, and amethyst. Silica combined with metal oxides forms a group of compounds called silicates. Feldspar is potassium aluminum silicate. When this weathers, the potassium is removed and aluminum silicate is left in a pure state. This is kaolin, which when impure is called clay.



Galloway

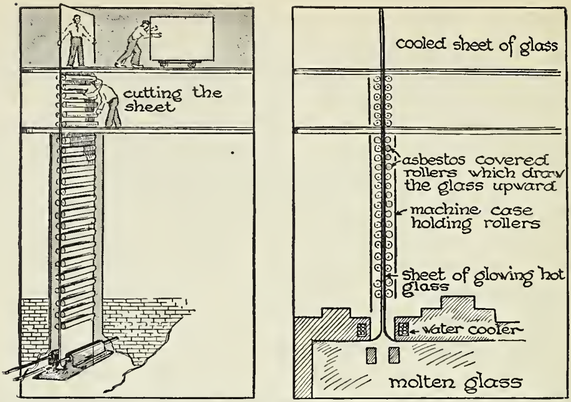
Laying hollow tile. Why is it used instead of brick?

Brick and Tile. The decay of feldspar produces clay. Running water in years gone by has carried this clay from its source and deposited it, forming deep beds in many places. These deposits are the clay pits of today. The modern process of making bricks differs from the primitive method only in the use of machinery in molding the clay, in cutting the bricks, and in the fact that bricks are dried in kilns or ovens with artificial heat. Pressed brick is made by machinery, where clay is molded under pressure and then baked in the kiln. Different mineral substances in the clay give it color; for example, iron gives the red color to common building brick.

Hollow tiles which are made of clay are used extensively for building materials. These are molded into the desired forms and then baked. Roofing tiles, which are frequently used in place of wooden shingles, are made in a similar way. The glaze put on tiles is made by dipping them in a watery solution containing colored compounds which melt at a low temperature, then the tile is rebaked and the glaze appears.

Glass. In the early days glass was so scarce that it was worth its weight in gold, although now it is one of our cheapest and most common articles. Think of buildings without glass, no electric light bulbs, no lamp chimneys, bare exposed flames for automobile headlights, no lenses for cameras, no microscopes or telescopes for science investigation, no glassware for science laboratories or use in the home. What a different world it would be! And yet with no silica there would be no glass. The raw materials for glass making are silica, usually supplied from quartz sand or crushed sandstone, chalk or limestone, and sodium or potassium carbonate. When these are melted together, they unite chemically, forming glass. When this is cooled, it is solid and transparent; when in a hot plastic state it can be formed into the various forms which are familiar to you. Different varieties and colors of glass may be produced by adding other metals and compounds to the mixture. Lead compounds are added when the product is for making cut-glass vessels, since lead glass has greater luster than other kinds. Pyrex glass will stand high and sudden temperature changes because the boron and aluminum used in it make a glass having low expansion for heat changes.

Fused Quartz. Fused quartz, transparent like glass, is made of silica alone. This has but recently been made on a commercial scale, and it is still rather expensive. Chemical vessels made of fused quartz can be heated red hot and plunged into cold water without danger of breaking. This is possible because of the small expansion of quartz when heated. Fused quartz, sometimes called "quartz glass," permits the ultra-violet rays of the sun to


cutting the sheet
cooled sheet of glass
asbestos covered rollers which draw the glass upward
machine case holding rollers
sheet of glowing hot glass
water cooler
molten glass

Sectional diagram showing flat glass vertically drawn in continuous sheets from furnace to finished product. It is perfectly annealed as it is drawn.

penetrate it, while ordinary glass excludes the greater part of these rays.

Carborundum. Silica (sand) mixed with carbon and common salt is heated above 6000° F. in an electric furnace to produce carborundum, which stands next to the diamond in hardness. Carborundum is used as a common abrasive and replaces the diamond dust in grinding glass and very hard objects for which the diamond was formerly extensively used.

Infusorial Earth. There are microscopic one-celled plants called *diatoms* which secrete shells composed of silica. Many years ago deposits of these shells accumulated under water and at a later period these were elevated. There is an extensive deposit of this character found at Richmond, Va. The material appears to be a fine white powder, extremely fine, and of great hardness. It has been given the name *infusorial earth* and is used as a polishing powder. Under the microscope the shells show beautiful and intricate designs.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same words may be used more than once.

mica
compounds
element
combined
land
ocean
glass
minerals
rocks
free
electrons
deposits
man
silica
necessity
underground
silicates
crust
oxides
fused
compressed
sulphur

Salt is a (1)____ of both (2)____ and other animals. It can easily be obtained from the (3)____, but in many places (4)____ are found within the (5)____ of the earth. A very important chemical (6)____ yellow in color found (7)____ in large deposits in Louisiana and Texas is (8)____. This is melted (9)____ and forced out through pipes by (10)____ air. Silicon dioxide or (11)____ is combined with (12)____ of metals in several (13)____. These (14)____ are important raw materials for the (15)____ industry.

PROBLEM TEST

By some accident in the printing room, some words have become misplaced in the following paragraph. Try to tell how they were originally placed before the accident happened. Write the words as you think they should go, making the list in numerical order.

(1) *Force* of (2) *pure* water yields salt and (3) *sea* water pumped into salt mines forms a (4) *white* brine which can be brought to the surface by (5) *evaporation* of compressed (6) *acid.* (7) *Carborundum* is mined chiefly for use in making sulphuric (8) *air,* although it is much used in (9) *abrasive.* Quartz, (10) *glass,* the amethyst, and the (11) *diamond* are all related to each other in composition. They are really all silica with (12) *much* variation due to small differences in composition or (13) *sandstone.* (14) *Flint* makes much use of silica which is usually taken in the form of (15) *salt* sand or (16) *impurities.* (17) *Sulphur* is next to the (18) *opal* in hardness and is a (19) *slight* used (20) *industry.*

THE REVIEW SUMMARY

In preparing the summary of this unit, you are first to get the big generalizations, then work out the details of facts and principles which contribute to these. Some of the generalizations for this unit are as follows. Can you add others?

1. The earth holds many materials that are useful to man.
2. Many large industries depend upon these materials for their raw materials.
3. Man by the use of science is able to fashion new materials out of those found in the earth.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT *write numbers of all statements you believe are true. In another column under* INCORRECT *write numbers of untrue statements. Your grade = right answers × 2½.*

I. **Granite is an igneous rock:** (1) of metamorphic origin; (2) containing carbonate; (3) containing feldspar and quartz; (4) quickly eroded and weathered; (5) hard and durable.

II. **Crude limestone from the earth is:** (6) sometimes changed in the earth into marble; (7) sometimes changed into granite; (8) an igneous rock; (9) produced in the earth by action of carbon dioxide upon lime; (10) just as durable as granite.

III. **Lime is:** (11) a metamorphic rock; (12) made when limestone is heated very hot; (13) used in making limewater; (14) used in lemon-lime soda water; (15) used in making mortar and plaster.

IV. **Calcium carbonate ($CaCO_3$) is:** (16) the main constituent of real pearls; (17) present in clay; (18) an important raw material in making cement; (19) decomposed by an acid; (20) one of the minerals in granite.

V. **The sources of useful metals are:** (21) iron comes from peat; (22) copper from bauxite; (23) lead from corundum; (24) zinc from galvanized iron; (25) gold from gold-quartz veins.

VI. **Silica is an important raw material because:** (26) it is needed to make glass; (27) it makes quartz crystals; (28) it is the binding rock in granite; (29) it is often beautifully colored; (30) a constituent of clay.

VII. **Aluminum is a valuable metal because of its:** (31) low density; (32) insulating properties; (33) resistance to tarnishing in air; (34) beautiful color; (35) extreme hardness.

VIII. **Common salt:** (36) may be taken from the ocean; (37) may be mined; (38) is freed from impurities by roasting; (39) is a necessity of animal life; (40) is a constituent of glass.

PRACTICAL PROBLEMS

1. Make the following headings on a large sheet of paper.

Kind of Rock	For What Used	Reason for Its Use in This Way

In the column at the left you will place these names: granite, quartz, mica, sandstone, limestone, feldspar, and marble. In the second column name two uses of each rock or mineral if you can, and in the third column give one or more reasons why it is adapted to the use named.

2. How is it that a plumber can "wipe a joint," using melted lead and a cloth, and not be badly burned?

3. Which of the following building materials, or the materials from which they are made, were at one time deposited under water? 1. granite. 2. gneiss. 3. marble. 4. slate. 5. brick. 6. cement. 7. quartz. 8. limestone. 9. sandstone. 10. asbestos.

4. How does the chemical composition of plaster on the walls of a house compare with limestone in the ground? Try to show all the chemical changes from calcium carbonate in limestone to calcium carbonate in hardened plaster.

5. Why are gold, platinum, and silver so much more expensive than iron, tin, and copper? They are not as useful for rails, bridges, or skyscrapers.

LIBRARY RESEARCH READING

1. Colonial pewter.
2. Ours is an age of metals.
3. How steel cables are made.
4. Metals and the world's money.
5. How a block of marble is transformed into a statue.
6. The process of electroplating.
7. Salt through the ages.
8. The story of Charles M. Hall and aluminum.
9. Why is sulphur so valuable to the world?
10. Common useful alloys.

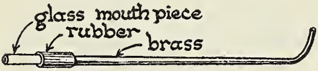
SCIENCE FOR LEISURE TIME

1. **Steam from chemical action.** Get a hard lump of quicklime from a mason. Put it in a large mixing bowl. Pour water upon it, a tablespoonful at a time as fast as it is absorbed. Continue until after the chemical action starts. What is this new product? What practical uses has it?

2. **Building stones.** Make a collection of samples of building stones, natural and artificial, for your own museum.

3. **Metals and ores.** Start a collection of metals and ores. Small bottles of uniform size, carefully labeled, will be good for the metals. A cigar box divided into sections with a glass cover will be better for the ores.

4. **Make a blowpipe.** By carefully bending the small end of the spout from an oil can, you can make a serviceable blowpipe. Connect a glass mouthpiece to the large end with rubber tubing. See if you can get metallic lead from powdered red lead with the blowpipe and a block of charcoal. Follow the demonstration in the text. A trained chemist can deliver a steady current of air from his mouth; he can blow out from his mouth while he breathes through his nostrils. Practice until you can do this.



SCIENCE CLUB ACTIVITIES

1. **Metal-mineral contest.** Choose sides. Give each member a sheet of paper. This is a contest to see which team can produce the longest list of materials that come from the earth and which have been used in making the school building and equipping it with regular fixtures. (Do not include museum specimens and apparatus.) Give the members of each team 20 minutes for search, after which each team will meet in separate rooms to pool their items. Allow 10 minutes for this. Then at a previously designated time, both teams meet and the captains pass in to the referee one list each for their teams. The referee reads each item; it is submitted for argument if any disagreement arises, but the referee decides. Each point allowed is marked on the blackboard. The total score of each side is eventually the sum of the allowed points.

2. **A club excursion.** A visit to the source of a valuable product from within the earth's crust. This will vary with your locality. It may be a salt mine, coal mine, oil or gas well, stone quarry, gold, silver or copper mine, sulphur mine, or it may be only a clay pit or a gravel bank.

3. **A silica exhibit.** For this meeting, ask members to collect and bring for exhibition specimens of quartz, rocks containing silica, as mica, feldspar, asbestos, etc. Also articles that are made from silica products, as glass, water glass, etc. Many semiprecious stones are quartz or silicates.

4. **Lead and silver trees.** If you dip the end of an iron nail into a solution of copper sulphate, it quickly becomes coated with copper. Iron has the power to replace copper. The iron goes into solution, making iron sulphate, and the copper comes out copper plating the nail. Other metals have similar replacing power. Zinc will replace lead, setting lead free. Copper will replace silver, setting silver free.

Lead tree. Cut a piece of zinc and bend thin strips out from the central trunk to make branches and form the tree. Bend the base so that it will stand upright. Place in a small glass jar. Pour over it enough lead nitrate or lead acetate solution to cover it. You will see the tree form right away.

Silver tree. Do this in a similar way but use a half-inch strip of copper. Make branches shorter so the tree can go inside a wide test tube. Silver salts are expensive, so use a smaller receptacle. Cover the tree in the test tube with a solution of silver nitrate.

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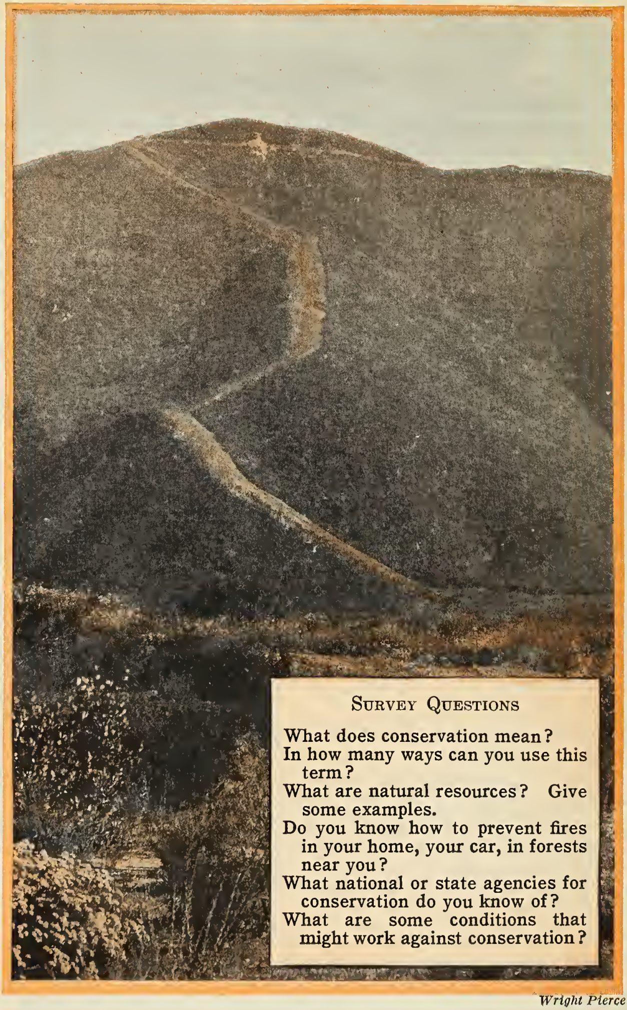


Survey Questions

What does conservation mean?
In how many ways can you use this term?
What are natural resources? Give some examples.
Do you know how to prevent fires in your home, your car, in forests near you?
What national or state agencies for conservation do you know of?
What are some conditions that might work against conservation?

Wright Pierce

UNIT XIII

CONSERVATION FOR HEALTH AND WEALTH AND SAFETY

PREVIEW

Perhaps you have lived in some region where a few years ago oil was found in abundance, but where today the gaunt derricks remain as mute evidence of man's greed. Or you may have seen some abandoned mine where a few years ago there was a flourishing town, but where now all is deserted. Or perhaps you have driven through a cut-over region where stumps and a few bushes show there was once a lofty forest. All of this waste and desolation would be unnecessary if man were not so anxious to get all he can out of his environment in the quickest possible time. Conservation means efficient use of the earth's storehouse of plenty — not waste. You may have seen a garden where the plants were expected to produce a crop struggling in vain against weeds, insects, and other foes. Every garden plant was surrounded by hazards against which fulfillment of its life purpose was impossible. For every seed planted by man, nature planted a thousand weed seeds. Here is a lack of conservation of another kind. To get the most out of our environment, we must improve it. It is only when the environment is made favorable, and intelligent care used against these plant enemies, that our gardens will flourish. The successful farmer knows how to care for his plants, his farm machinery, and the human help he employs. He practices conservation.

Like the plant in the garden, every active human being is surrounded by hazards which may maim him, injure his health, or even deprive him of life. As we continue to make and use new machines in the home, and in commerce and industry, the hazards increase. It is well to know how to apply first aid to the injured, but how much more worth while it would be if people would take efficient means of safeguarding themselves against accidents.

But some accidents will happen in spite of all we can do. Machines are not perfect and man is careless. We must, therefore, be prepared to help conserve human life by making our factories, mines, and other industries as safe as humanly possible. Here again we can practice conservation.

Fire, although a good servant, makes a bad master. Anyone who has been through the experience of fighting a forest fire knows only too well the devastation and ruin such a fire brings. Fires in our own homes may, in a few minutes, wipe out the savings of years. Control of this enemy is certainly a part of the conservation movement.

Our country has owed its prosperity in the past to the fact that it has been well supplied with the raw materials that are needed for manufacturing, farming, etc. Our lands were covered with forests, and when they were removed, the soil underneath them was rich and ready for the planting of crops. Wild life was found everywhere. Water supplies were abundant in most parts of the country, from which power could easily be obtained. Mineral wealth has been ours for the taking, and we have left few opportunities untaken. What has been the result? Since the coming of the first colonists, in many parts of the country we have almost exhausted our available supply of trees, causing floods and droughts; we have wasted our coal and oil resources beyond belief; and we have destroyed much of our wild life. We have now come to realize that if we are to live in prosperity, we must not waste our heritage and that we must do all in our power to conserve and protect the little we have left of these riches, particularly some of our wild life, game, fish, and birds, and forests. In Theodore Roosevelt's administration the policy of expanding our national parks and national forests was inaugurated and this policy has since been carried out. At the present time, this country has embarked on a campaign of conservation which is more comprehensive and far reaching than any planned by Theodore Roosevelt. The immediate cost will be great, but the next generation in our country ought to reap the harvest. And as science continues to find new ways of getting and using power and conserving our raw materials, conservation will become an actual fact instead of a slogan.

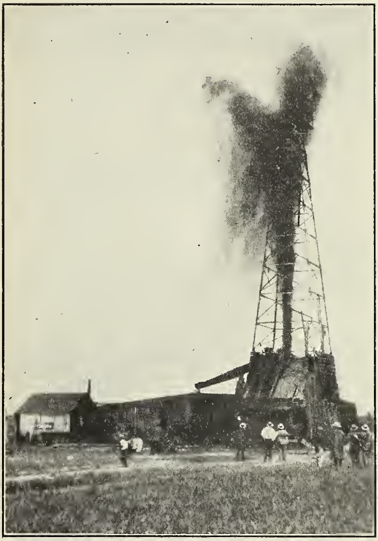
Before you begin your study of this unit, think over your previous work in science to see if there are any important ideas or generalizations that you can use as a foundation to build on in this unit. Some of these are the following, and you can doubtless add to the list:

1. Oxygen helps things burn.
2. Dry material burns better than wet.
3. The kindling point of different substances varies.
4. There are many fire hazards.
5. Mountain areas contain the most forests.
6. Forests protect watersheds.
7. The velocity of a stream determines its carrying power.
8. New mountains have steeper sides, consequently there is a more rapid erosion there.
9. A balance of life exists in nature.
10. If we disturb the balance, great changes may occur.
11. Man often changes and controls the balance of life.

PROBLEM I. HOW MAY WE BEST CONSERVE OUR NATURAL RESOURCES?

What Are Our Natural Resources? What do we mean by natural resources? They are those things which nature has given us in the form of water, minerals, oil, forests, wild life, and all other things that are found in our natural environment. In some parts of the country we find abundant mineral wealth, in another potential horse power from the rivers or mountain streams, some coastal waters having a wide continental shelf contain great numbers of fish, while our plains supply cattle with forage, and our forests, if properly cared for, should last for centuries. The pages that follow will show us how we may keep from wasting these natural resources which have been so lavishly bestowed on this country, making it one of the richest countries of the world.

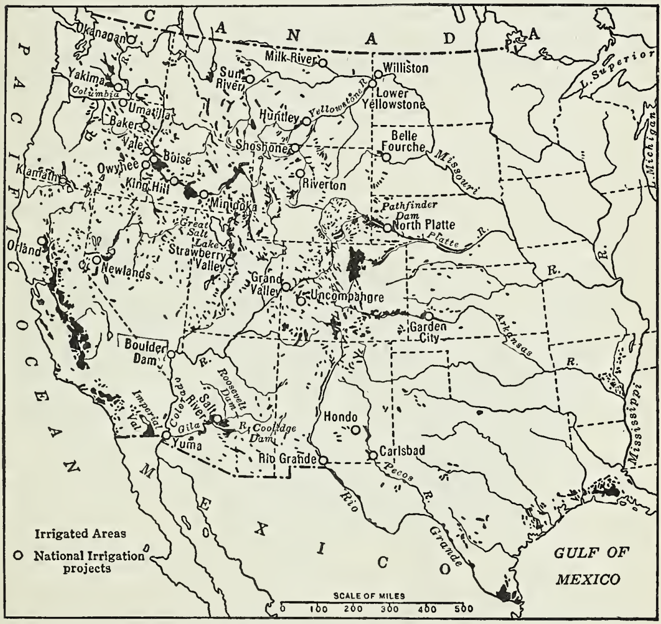
Conservation of Coal, Oil, and Mineral Resources. The hard coal deposits of this country are over 16,000,000,000 tons and are being used up at the rate of over 75,000,000 tons a year. The bituminous deposits are much larger, being much more widely scattered and containing much more coal. It is estimated that there are in this country and Alaska about 3,536,000,000,000 tons and this has been mined at the rate of over 600,000,000 tons a year, although in 1932, on account of the economic depression, there was less than 360,000,000 tons mined. This shows there is enough to last us for many centuries to come. Our supplies of oil and natural gas will go much sooner in spite of all we can do, because of the rapidly increasing demands for these products in automobiles, airplanes, and motor-driven vessels. Over 800,000,000 barrels were taken out in 1932. Sooner or later most of our heat and power will have to come from other sources. Doubtless other fuels, such as alcohol, will be used in the internal combustion engine. The sun is being harnessed and the "white coal" of our rivers is already being used. Electricity will some day almost entirely take the place of steam, and the water power of our country will do the work that is now being done by coal and oil. Our supplies of minerals will last for many years to come, and there are parts of the earth still untouched, but there has been much waste in the past.



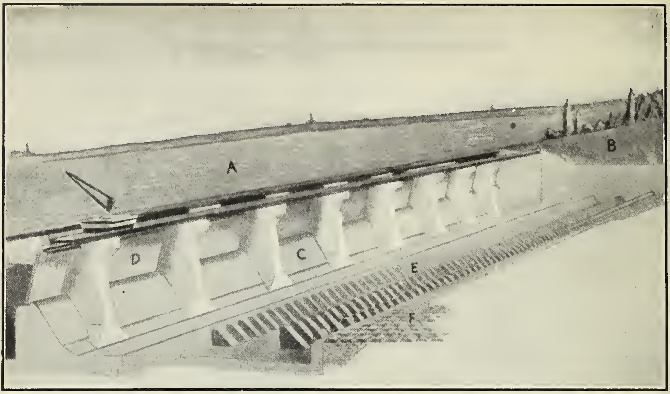
A gusher. What dangers are there from this oil well?

The gold found in old Egyptian tombs was probably from native nuggets that could be shaped just by hammering. It is not likely that they had the knowledge of extracting metals from low-grade ores such as we find it profitable to work today. And so for the future, as the richer ores are exhausted, new chemical means must be devised to extract metals from the poorer ores which we discard today as unprofitable. More metal has been extracted from ores and used within the last 30 years than in all previous time since the beginning of the world. Applications of science have made this possible. In the future science will be needed more than ever in order to devise ways and means of supplying the world's needs. *Conservation here is efficient utilization.*

Conservation of Water. Water is conserved, first, by collecting and holding in reservoirs the water that would otherwise run off and be lost, and secondly, by making use of the power developed by falling water. We are doing this work with such undertakings as the great Boulder Dam project, the great Hetch-Hetchy reservoir, and the scores of Reclamation Service projects in different parts of the West. Already projects in this country have begun to utilize almost half the potential water power of this country,


CANADA
PACIFIC OCEAN
MEXICO
GULF OF MEXICO
Okanagan
Yakima
Columbia
Umatilla
Baker
Vale
Boise
Owyhee
Klamath
King Hill
Minidoka
Milk River
Sun River
Huntley
Yellowstone R.
Shoshone
Riverton
Williston
Lower Yellowstone
Belle Fourche
Missouri
Pathfinder Dam
North Platte
Platte R.
Great Salt Lake
Strawberry Valley
Orland
Newlands
Grand Valley
Uncompahgre
Garden City
Arkansas
Boulder Dam
R.
Roosevelt Dam
Salt River
Colorado
Imperial Val
Gila R.
Coolidge Dam
Yuma
Rio Grande
Hondo
Carlsbad
Pecos R.
Rio Grande
L. Superior
L. Michigan
Mississippi
R.
Irrigated Areas
○ National Irrigation projects
SCALE OF MILES
0 100 200 300 400 500

This map shows, in black, the principal irrigated areas in this country. The national irrigation projects are shown by circles.



A part of The Bonnet Carse Spillway 28 miles above New Orleans, just completed by army engineers at a cost of $3,500,000. More water can be removed through these gates (*D*) than would pass over Niagara Falls during the same period. The letters above are (*A*) Mississippi River, (*B*) levee, (*C*) concrete bays, (*D*) needle gates, (*E*) baffle plates, to prevent washing away by floods, and (*F*) stone slabs used for same purpose. This is a part of the flood control work along the Mississippi River.

which shows that along this line conservation is being developed rapidly. In another way, we are not only conserving our water, but also making the best use possible of it. Rivers placed under control mean an even instead of an irregular water supply, navigation all the time instead of only at flood seasons, and a supply of water during drought conditions. If water had been stored in great reservoirs somewhere below the point where the Platte, Arkansas, and Missouri rivers issue from the western mountains, and allowed to flow out in great irrigation ditches, much of the suffering caused by the drought of 1934 on the great plains might have been avoided.

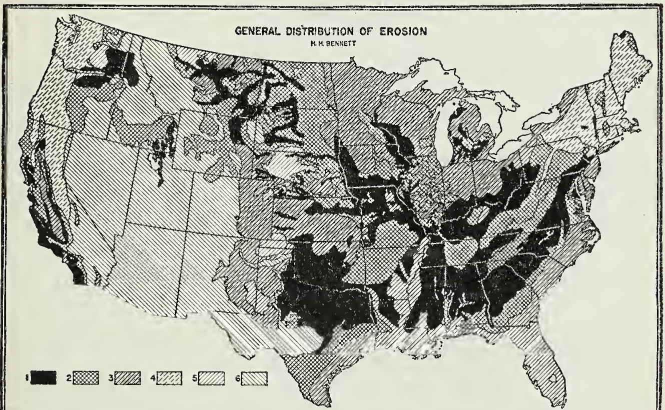
Conservation through Flood Control. After the great flood of 1927 in the Mississippi Valley, plans were made by government engineers for control all along that great river. In this problem replanting of forests was out of the question because great farms, towns, and cities occupied the places once covered by forests. So a plan was worked out by means of which the river could be diverted into especially constructed spillways which would take care of the flood waters and carry them through parts of the country where no great harm could be done. In addition to this the plan called for the raising of all the levees three feet, which would take care of the greatest rise in the river during floods. The project is already over half finished. In the recent flood of March, 1933, in the Ohio Valley much less damage was done than in similar earlier floods because of the complicated flood protection work in that district.

Muddy Water Prevents Soil Conservation.

Demonstration 1. Relation of Muddy Water to Run-off.

Close small ends of two glass chimneys with cheesecloth. Fill both 3″ deep with fine to medium sand. Mix a handful of garden soil in a pint of water. Strain this through a cloth. This will give a muddy water without any coarse particles in it. At the same time pour muddy water into one chimney and clear water into the other chimney to fill them to the same level. Observe in which chimney the water soaks in and passes through the sand first. Make a statement to show the application of this to soil erosion.

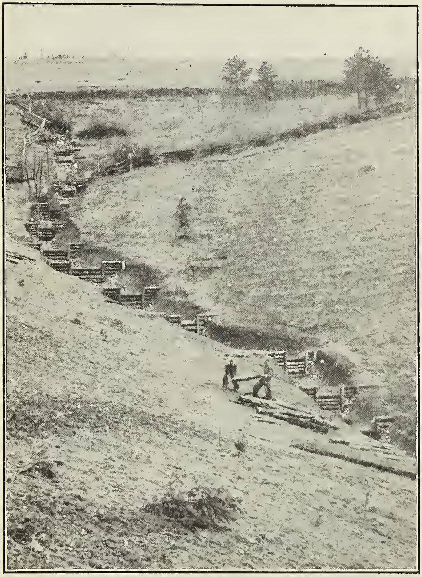
You have all noticed that a plowed area on a hillside allows more water to run off than a similar area covered with grass. And you have probably found that this water that passed off from the



Erosion areas in the United States. 1, area of most serious erosion; 2, harmful erosion widespread; 3, comparatively little erosion because of flat surface; 4, erosion generally not serious; 5, much serious wind erosion; 6, much erosion from overgrazing. In which area do you live?

plowed field was loaded down with mud. The demonstration above explains why this is so. Vegetation covering soil prevents rain from forming muddy water and so it soaks in rather than runs off. Where silt or mud is formed in water, this sediment goes into the ground and clogs up the tiny holes in the soil so that the water runs off instead of being absorbed.

Uses of Forest Conservation. Closely connected with conservation of water is another natural resource — our forests. The supply of water to rivers depends largely on the forest blanket at the sources of these rivers. The Dayton flood of a few years ago and the more recent Mississippi floods are closely connected with the fact that the watersheds of the Ohio and Mississippi rivers have been stripped of their forests. As civilization progressed westward, with its increasing number of people, the woodlands were cut down, and farms and grazing lands took their place. Then came the growth of towns and cities, and still more trees were removed, so that now in many places water of heavy rains is not held in the ground, but runs off at once, carrying soil along with it. Wherever the forest cover is gone, as happens after a forest fire, there rain storms carry off the rich soil from the earth's surface, and take it away to places where it will be of little value. The annual wastage of soil in this country amounts to 1,500,000,000 tons of soil.



American Forestry Ass'n.

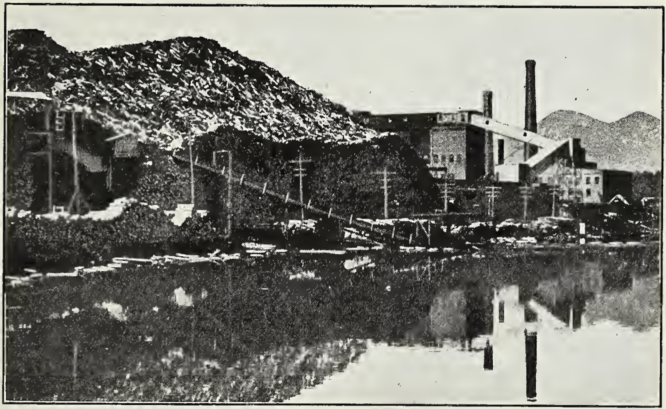
The construction of check dams in the Tennessee Valley is one method of checking erosion.

This soil contains over 126,000,000,000 pounds of mineral matter that plants use as food, which is estimated to be worth $2,000,000,000 a year to this country. The relation of erosion and floods to forest fires is shown by the following table, which was made after the devastating flood in California during the storm of December 30, 1933, to January 1, 1934.

Watershed	Rainfall, Inches	Per Cent of Area Burned	Per Cent of Area Unburned	Run-off, Maximum, Cu. Ft. per Second	Erosion, Cu. Yds. per Square Mile
Verdugo . .	19.13	67	33	1000	50,000
San Dimas.	16.85	0	100	51	56
Haines . .	11.26	68	32	1000	67,000

A similar experience was repeated in October, 1934, in the same region, this time after a 6-inch rainfall.

Conservation after Forest Fires. When a mountain area has been burned over, the first thing that has to be done is to get grass, weeds, and small bushes to grow so as to hold the soil in place. A recent experiment was made by sowing seed by airplane in an impassable mountain area in California. Here 18,000 pounds



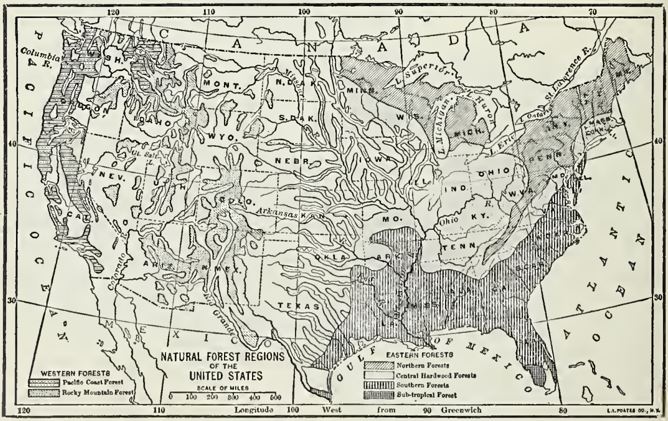
Galloway

A paper pulp mill. See the great pile of logs. How are these used in the paper industry?

of mustard and clover seeds were sown in four days over an area that would have taken weeks to sow by hand. This is one way in which the modern machine is helping our conservation program. Another means of preventing rapid run-off and hence erosion is the construction of check dams along gullies. Here numerous small dams are placed in the gullies where the water runs off; these dams collect the soil and hold it, thus preventing it from being carried far down the mountain. Of course replanting of trees and bushes must take place as soon as possible after the fire has destroyed the mountain cover.

Forests Supply Wood. Our forests supply us with wood for fuel, timber, trim, and countless other purposes. The amount cut each year is enormous, as much as 44,510,000,000 board feet, although in 1932 only 10,159,000,000 board feet were produced. In addition, in 1929, 34,110,529 cords of firewood and 1,485,759 cords of pulp wood were cut. Already our supply of hardwoods is almost gone, and the paper industry is now using the forests of Canada as well as our own. What are we going to do about it? Conservation of our forests is the only answer.

Our National Forests. The nation has under its control a large area, principally in the West, which consists of over 221,000,000


69
NATURAL FOREST REGIONS
OF THE
UNITED STATES
SCALE OF MILES
0 100 200 300 400 500
WESTERN FORESTS
Pacific Coast Forest
Rocky Mountain Forest
EASTERN FORESTS
Northern Forests
Central Hardwood Forests
Southern Forests
Sub-tropical Forest
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
Longitude 100 West from 90 Greenwich
120
110
100
90
80
70
40
30
WASH.
ORE.
CAL.
IDAHO
NEV.
MONT.
WYO.
COLO.
ARIZ.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KAN.
OKLA.
TEXAS
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MICH.
IND.
OHIO
KY.
TENN.
MISS.
ALA.
GA.
FLA.
N.C.
S.C.
VA.
W.VA.
PENN.
N.Y.
ME.
MASS.
CONN.
MD.
DEL.
Columbia R.
Ut. Salt L.
Colorado R.
Rio Grande
Arkansas R.
Missouri R.
Ohio R.
L. Superior
L. Michigan
L. Huron
L. Erie
L. Ontario
St. Lawrence R.
L.L.POATES CO., N.Y.

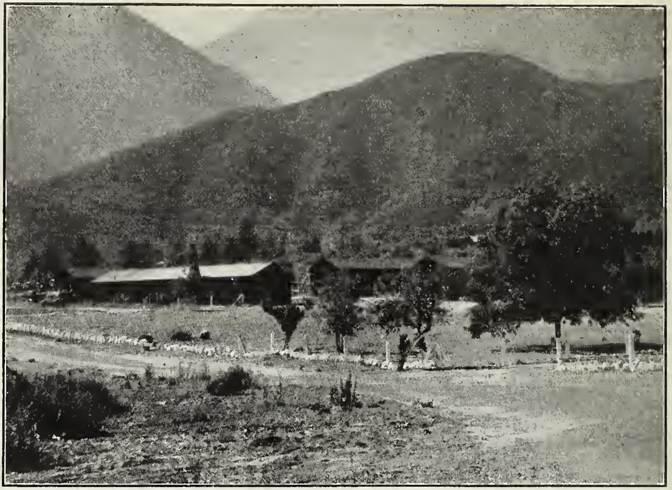
In what areas are the national forests of the United States? Where are the greatest mixed forests? The most pine? The largest trees?

Wright Pierce

A flood control dam being built by members of the Civilian Conservation Corps. Can you make out a list of all the kinds of work now being done by this organization?

acres. Of this, about 170,000,000 acres are in national forests. Many states have made state parks or forest reserves. New York, for example, has over 2,200,000 acres; Pennsylvania over 1,200,000 acres of state forest reserve; while Minnesota and Washington each have over 1,000,000. In Illinois two national forests of nearly 600,000 acres are planned, while other states are planning a return of the acreage which is too poor for farming to brush and forest so that water supplies may be better protected. California is fortunate enough to have over 13,000,000 acres of national forest within her borders, besides several national parks. Idaho, Montana, and Oregon together have over 41,000,000 acres of public forest land. Since these states have the headwaters of several important rivers, it is easy to see how forest conservation will help regulate water supplies of these rivers.

Forestry. In addition to this, both public and private forests are being cared for much more than in the past. Trees are treated

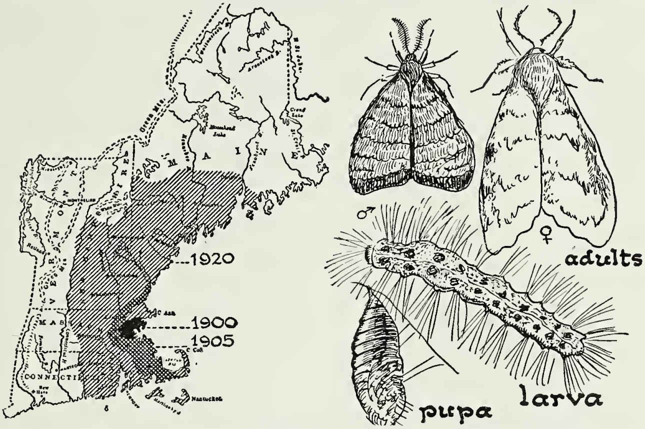


Wright Pierce

A C.C.C. camp in the foothills of the California mountains. Visit one of these camps if you have an opportunity.

as a crop to be harvested and the ground to be replanted. Many states have schools of forestry, where young men are being trained to become foresters. State nurseries and plantations of seedling trees are maintained, and millions of young trees are being set out and cared for both in forest reserves and in private woodlands. The establishment of a shelter belt about a thousand miles long and a hundred miles wide in the Central West is planned. This might help to prevent droughts such as occurred in this region in 1934. The work of the Civilian Conservation Corps promises to become a great factor in the conservation of our forests, and should be continued. In 1933 there were 300,000 young men located in nearly 1500 camps in all parts of the country. These men built 3944 miles of roads and fire prevention trails, 1026 miles of fire breaks, and cleaned 45,000 acres of land from fallen timber and other fire hazards. California in 1924 had 1932 forest fires, which devastated 762,150 acres. In 1934, while there were over 2054 fires, only 82,773 acres were burned, this testifying to the efficiency of the C.C.C. there. Campers and hikers are beginning to realize how easily fires can be set and are exercising care to prevent them. The state and national forest service is constantly on guard to prevent damage from forest fires, as well as working to improve forest conditions, but we must help if our forests are to remain.

Insect Enemies of the Forest. Trees have many insect enemies. Anyone who has driven through parts of New England has undoubtedly noticed thousands of acres of trees that have been stripped of their leaves by the gypsy moth, which was accidentally imported from Europe into Massachusetts in 1869. Since that time it has spread rapidly as far west as Pennsylvania and throughout all the New England states, and has done millions of dollars of damage. The country has spent many millions of dollars in attempting to control it, but has been only partly successful. It is said that there are over 200,000 species of insects that feed on forest trees alone, some feeding on leaves, some on the wood or sap, while others damage the roots.



The gypsy moth was introduced into New England from Europe in 1869 and since that time has spread over the area shaded in the cut. It costs the New England states millions of dollars every year and is still out of control.

How Insect Pests Are Controlled. These imported pests are best controlled by finding their natural enemies and bringing them from other lands to help us in our continuous insect war. The United States government has a number of men in the field who are studying the enemies of these pests. Then these insects are imported to this country, bred here, and released to prey upon the pests. As early as 1888 we imported ladybird beetles from Australia to feed upon the scale insects in California and the former have multiplied to such an extent that the scale insect on which they feed is now under control. It is hoped that the imported Calosoma beetle will do the same thing with the gypsy moth. Nature's own way of controlling pests is probably far more effective than the artificial methods of man.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

cutting
replanting
regulate
largest
smallest
coal
all
adding
potential
oil
soil
storage
insect
insects
Boulder
floods
ditch
areas
minerals
forest
half
water
conserved
dirty
fire
burned
power
unburned
smoky
floods
irrigation
national
wastefully
state
run

Our natural resources of (1)____, water and (2)____ must be (3)____ if our country is to keep its place as a leader. We are using up our mineral resources (4)____, especially our fuel (5)____ and some useful minerals. We have already harnessed almost (6)____ of the (7) ____ energy of the water power of this country, and have utilized much of it for purposes of (8)____ and (9)____. One of the (10)____ projects now well toward completion is (11)____ Dam. Conservation of forests is necessary if we are to prevent future (12)____, for forests (13)____ the (14)____ off, as is proved by recent experiments in California with burned and (15)____ forest (16)____. Our forest enemies are many, including (17)____ and (18)____ as well as man. Our hope for the future lies in (19)____, conserving the forests, greater protection against (20)____, and more successful fighting of (21)____ pests. The federal and state governments are (22)____ each year to the forest areas for the purpose of conservation of water.

PROBLEM TEST

During a severe storm in California, rain fell in two areas as follows: area #1, 19.13 inches; area #2, 16.85 inches. Both areas were on the sides of mountains. Two thirds of #1 had recently been burned over, while all of area #2 had not been burned. On area #1 the erosion was found to be 50,000 cubic yards to the square mile, while on area #2 it was 56 cubic yards to the square mile. In area #1 the run-off was 1000 cubic feet per second, while in area #2 it was 51 cubic feet a second. Which of the following events took place as a result of these happenings?

1. Area #1 was visited by a severe flood.
2. Earthquakes were caused in both areas.
3. Many rocks and boulders were carried down in area #1.
4. Area #1 lost a large portion of its soil available for planting.
5. The water in area #1 largely soaked into the ground.
6. Much water was stored in the ground in area #2.

Give reasons for the happenings that you have selected by matching with the reasons given below.

1. Earthquakes are caused by slipping along fault lines.
2. Wherever there is a protective forest cover, the water in that area is held in the ground so that it passes off slowly.
3. The erosive force of water increases in proportion to its velocity.
4. The erosive force of water increases in proportion to its volume.
5. Whenever the forest cover is removed, erosion takes place rapidly.

PROBLEM II. HOW IS CONSERVATION OF OUR WILD LIFE BEING EFFECTED?

Birds and Conservation. We have already seen that birds play a very important part in the control of both harmful insects and weeds. But unfortunately we have not protected these valuable assets as we should have, with the result that some have passed forever from the face of the earth. The passenger pigeons were so plentiful in the time of your great-grandfathers that they used to be sold in the markets for a cent apiece. A few years ago a Cincinnati zoo had one living specimen. Every effort was made and $5000 was offered for a mate for it, but none could be found. The death of the captive bird stopped further search. In more recent times the prairie chicken, the wild turkey, and the egret, which was killed for its plumage, have almost been exterminated. Fortunately bird lovers in the United States woke up before it was too late and as a result of their activities, several good laws have been passed which prohibit the killing of birds except during a short open hunting season. Do you know the open season on the game birds in your locality? In 1916 a treaty was made with Canada which protects birds in both countries while they are migrating. This was followed by a law in 1918 protecting migrating birds in this country. In1929 Congress passed a Bird Refuge Law which provides for the establishment of bird sanctuaries where all birds will be safe from hunters. Some already exist under private control in certain parts of the country, such as the Ward-McIlheny Bird Reserve in Louisiana and the Ramy Wild Life Sanctuary and the Mountain Lake Sanctuary shown in the picture on page 426. The latter were established by Edward Bok.

Wright Pierce

Cats are responsible for the death of many birds. Keep a bell on your cat in the daytime, and give the birds a break.

Conservation of Fish. Although this country cannot control fishing on the great continental shelf of the Atlantic, it does raise fish in its hatcheries which are liberated in the ocean and rivers. We have state and government protection of all game fish in our ponds and streams. We also have closed seasons on all game fish, which are protected during the egg-laying season. We also have limits set on the number of fish that can be caught and the size of such fish. In most states fishing licenses are issued and the money thus collected is used to restock the streams and ponds with sizable game fish. Many states and the United States Bureau of Fisheries maintain stations where different kinds of fish are hatched from the eggs and raised in rearing pools until they are able to take care of themselves. The astonishing number of 7,073,935,200 fish and fish eggs were put out from United States hatcheries in 1932. In addition many states maintain hatcheries, but in spite of this, our fish, especially those used commercially, are decreasing rapidly.

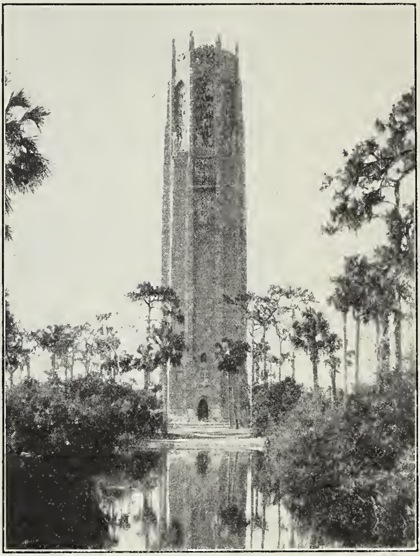
Courtesy Nat. Ass'n of Audubon Societies

A bird sanctuary. Of what value are such areas?

Conservation of Shellfish. For a good many years, our supply of clams, oysters, and scallops has been decreasing because of overfishing. The oyster industry has now become an important business amounting to nearly $19,000,000 in 1929. Young oysters swim freely in the water before their shell grows, but they need a place to attach themselves when the shell is formed. So oyster growers put out stakes, matting, oyster shells, or wire netting on which to collect the "spat" or young oysters and then farm them by protecting them until they are of marketable size. On the western coast the abalone, which is considered a great delicacy, is protected by a long closed season. Many states limit the number of clams, abalones, etc., that can be taken in a single day.

Conservation of Crustaceans. Another salt-water delicacy which has been greatly overfished is the lobster, but the government is liberating annually thousands of little lobsters and the states have limited the size of the lobster that may be taken. Fines imposed for possession of short lobsters are helping to conserve these animals. Similar conditions exist in regard to crabs and other edible crustaceans.

Other Needs for Conservation of Living Things. The buffaloes as late as the middle of the last century were so plentiful that droves of several hundred thousand were frequently seen. And yet today there exist only a few thousands, and those are in captive herds. The great seal herds of Alaska would have gone the same way had it not been for the enforcement of drastic laws for their protection. The beaver in places has almost been exterminated, as has the sea otter of Alaska. There is no assurance that just because animals or plants are plentiful, they will remain so. In our conservation of living things we must not forget that conservation does not mean just protection; it also means helping certain forms to exist. Many fur-bearing animals such as foxes are now being raised for their fur and others are protected. Many deer and other wild forms of life are killed every year by coyotes and wolves, so many states pay a bounty for the destruction of these animals. In order to protect our fish and game, the



Galloway

The Bok bell tower at Mountain Lake, Florida.

Warren Boyer

These deer took their own photographs. This picture was surely more satisfactory than a dead deer. Deer and moose are protected in most areas by limited hunting seasons. What do you know about the game laws of your state?

various states have passed laws which protect all animals that are in danger of extinction. A good sportsman will obey these laws and will see to it that other persons less sportsmanlike will also obey them. Our wild flowers and plants also need protection. Never pick any rare flower and always content yourself with a few wild flowers of any kind. Photograph them instead.

A fish hatchery. In these tanks the fish eggs are hatched. Later the young fish are placed in rearing ponds until they are able to take care of themselves.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

game
bird
shell
egret
plant
setting
hatcheries
hatched
spawning
exterminated
native
number
birds
prairie
crustaceans
big
migrating
wild
flying
protected
themselves
turkey
lobsters
Mexico
fish
billions
animals
small
swimming
Canada
care
eggs

· Conservation of our (1)____ life is important. In comparatively recent times we have almost (2)____ several different birds, among them the (3)____ chicken, the (4)____, and the (5)____ (6)____. All (7)____ birds are now (8)____ by law from ruthless hunters. In addition, a treaty made with (9)____ and a bill passed in 1918 now protect (10)____ birds. Private and now public protection of (11)____ is given through the formation of (12)____ refuges or sanctuaries. Game fish are (13)____ in most states during the (14)____ season and a limit is placed on the (15)____ a person may take in one (16)____. In addition millions of (17)____ are (18)____ in government and state (19)____ and the young released after they are (20)____ enough to take (21)____ of (22)____. And (23)____ are also protected as well as other edible (24)____ fish. Many of our valuable fur-bearing (25)____ are now being raised for the market, and other wild life is protected from overhunting.

PROBLEM TEST

In a certain area a law was passed offering a large reward for the killing of all predatory animals, such as wolves, coyotes, and wildcats. This was done in order to protect a large herd of deer which had a range there. The region was surrounded by deserts and rough country so that the deer were not able to get away from the region. A large number of the enemies of the deer were killed, but shortly after this the deer themselves began to die in great numbers. What was the cause? *Select your answer from the sentences below.*

1. A large number of predatory animals came in from other parts of the country and killed them.
2. Hunters shot them.
3. They died of starvation.
4. They died of an epidemic of disease.

In the sentences that follow select the one that gives the best reason for your answer.

1. Because predatory animals could not easily get into this country.
2. Because the laws with reference to hunting had not been changed.
3. Because epidemics of disease were not prevalent in this area.
4. When their natural enemies were destroyed, they overpopulated the area in a short time.
5. Because of practice the hunters became better shots.

PROBLEM III. HOW CAN OUR NATIONAL LOSSES FROM FIRE BE REDUCED?

It is estimated that in the last 10 years fire took an annual toll of about $500,000,000, and cost us 150,000 lives in that 10-year period. Most of these losses were caused by carelessness in the use of matches, smoking, defective chimneys, and defective flues. It is estimated that 86 per cent of all the fires caused in the United States are unnecessary as they are due to carelessness. When we think of the very great losses from fire in this country as compared with those of other countries, we must take heed. In 1932 the city of New York lost nearly $18,000,000 by unnecessary fires, and at least ten other cities have losses averaging over $2,000,000. Forest and brush fires do enormous amounts of damage. There are on an average over 80,000 forest fires a year. In 1906 a brush fire got out of control at Berkeley, California, and burned over 600 houses, causing damage of $10,000,000 to property. In 1933 fire losses in the United States were $316,897,733, a reduction from the peak of $561,980,751 for 1926. While this gain is partly due to the reduction in values caused by our great depression, there has been a real gain, largely accounted for by the fact that forest fires were greatly reduced in 1933 over previous years.

The Wooden-Roof Menace. Many cities have areas crowded with wooden buildings which are covered with wooden shingles. After a prolonged period of dry weather, these are like tinder. A spark falling upon them may start a fire which will quickly spread, destroying thousands upon thousands of buildings. In the Salem, Massachusetts, fire of 1914, sparks and firebrands carried by the wind ignited the roofs of buildings a mile away from the fire. There were 1600 buildings burned, and the city suffered a loss of $13,000,000. Now, no building within the city may be reshingled and no new building may be erected unless it is to be covered with fireproof shingles. Paris, Texas, had an $11,000,000 fire in 1916. The cause of the rapid spread of the fire was given as wooden shingles. Bangor, Maine, in 1933 had a $3,500,000 fire, the rapid spread being largely due to shingled roofs. Building regulations for a city can be enacted by the city government so that all new buildings may be made safe against roof fires.

Reduction of Fire Loss. A severe loss often results from allowing a fire to gain headway before serious efforts are made to extinguish it. Every minute counts. One minute of headway

Wide World

A fire that burned 231 buildings and rendered 1500 persons homeless swept Auburn, Maine, in May, 1933. The rapid spread of the fire was due to wooden shingles. What other fires do you know that spread from this cause?

on the part of a fire may mean many minutes of additional work for the fire fighters. It is therefore important:

1. That the alarm be given to the fire department at the earliest possible moment.
2. That the city or town have an adequate number of firemen.
3. That the equipment of the fire department be inspected and tested at regular intervals to insure its proper working.
4. That the regular drill be held in every fire department so that the men will lose no time in getting the fire equipment into use at a fire.

Forest Fires. In 1933 one forest fire in Washington burned as much lumber as the total amount cut in that state in five years. It is estimated that each year there are on an average of 186,000 fires, large and small, which burn over 4,476,000 acres of forest land. 1926 was a year of very serious fires and, according to the Forest Service, that year over 23,000,000 acres were burned over. 73 per cent of these fires were caused by man, of which smokers

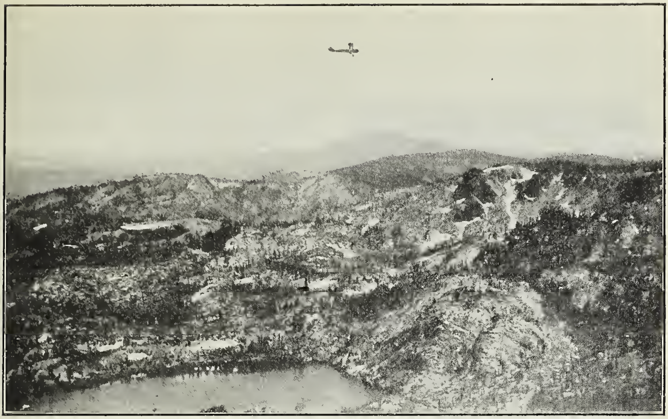
A. S. Peck, Courtesy U. S. Forest Service

This fire swept over 2500 acres in 3½ hours and almost burned this construction camp of the Moffett tunnel with its powder magazine containing three carloads of blasting powder.

caused about 16 per cent, railroads 14 per cent, and brush burning 12 per cent. If the money lost in fires could be put into public parks, buildings, waterways, road improvements, or even private enterprises, all the people of the country would benefit tremendously.

Forest Fire Prevention. With about 300 forest fires a day during the dry season, it is difficult for the small force of forest rangers to find them all until some have made considerable headway. The "spotters" or forest rangers use airplanes today and can thus cover the ground better and so locate the fires more speedily than formerly. Mountain peaks and lookout towers are still generally depended upon for common use and airplanes are only used for emergencies.

Mine Fires. In 1859 a fire was started in a coal mine at Smith Hill, Pennsylvania. At the present time the fire is still burning, $3,000,000 have been spent in a vain attempt to put it out, and over 14,000,000 tons of coal have been burned. The so-called Burning Mountain near Durango, Colorado, is probably caused by fire in an underground coal field.



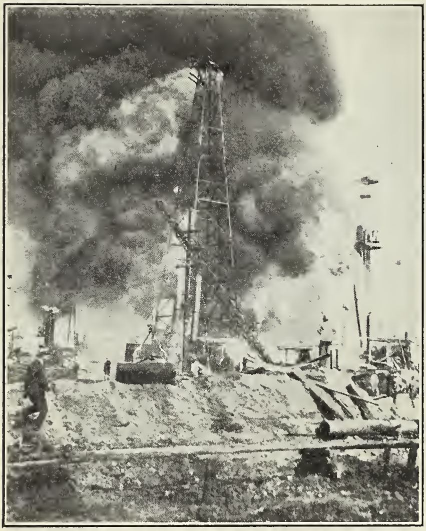
Courtesy U. S. Forest Service

Airplanes are used to patrol our forests. Of what benefit is this?

Oil Well Fires. When oil wells are drilled deep into the ground, they often strike gas or oil under tremendous pressure. When such a well "comes in," the pressure may be sufficient to start a fire caused by friction of sand, gas, and oil rushing through the casing. Such a gusher at Santa Fe Springs, California, burned for 26 days before it was finally conquered. A well at Oklahoma City, Oklahoma, recently went wild and steadily poured out 60,000 barrels of oil a day into the air with about 100,000,000 cubic feet of gas. The oil line leading into the North Canadian River near by caught fire and much damage resulted.

How Oil Fires Are Brought under Control. Oil wells which are to be put under control are capped by a great nipple which is placed over the mouth of the well. This device can only be anchored over the mouth of the well with great difficulty even when the well is not on fire, but when it is, it is a very much more difficult matter. Men in asbestos suits creep up as near to the fire as possible and place there a charge of nitroglycerin, which is set off by electricity. The explosion causes such a draft of air that usually the flame at the top of the well is blown out temporarily, thus enabling the workers to cap the well before it can ignite again.

Fires Started by Natural Causes. We have seen that lightning is a source of much damage to the forests, especially in mountainous regions. Lightning has also caused some very serious oil fires. A bolt striking a great reservoir of the Union Oil Company in California a few years ago destroyed several million dollars' worth of oil before it could be put out. Earthquakes have been responsible for great fires, as was seen after the San Francisco earthquake in 1906, when a property loss of $400,000,000 was caused. The earthquake destroyed the water mains and thus prevented the fighting of the fire. Volcanoes have caused enormous fire destruction. Hot lava flowing from volcanoes has not only destroyed vegetation but buildings and villages as well. On May 8, 1902, Mt. Pelée, on the island of Martinique, exploded, sending down a black cloud of superheated gas on the city of St. Pierre. In a space of two minutes practically all the 32,000 inhabitants of the city were killed, while fire destroyed all the buildings and 19 ships in the harbor. But the people of Martinique have built up a new St. Pierre on the same site as before, ignoring the danger of such a location. Will not science in the future step in and tell us the safe and unsafe places in which to locate our cities? This would go far toward conserving human life and property. If, in addition, all new buildings constructed were made fireproof and earthquake proof, we would go still further toward conservation of lives and property.



Wide World

An oil well burning at Santa Fe Springs oil field. Why are such fires difficult to extinguish?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

man
55
$617,000,000
volcanoes
100
5
lightning
burning
$916,000,000
extinguish
75
cities
70
lumbering
10
85
greatest
50
carelessness
earthquakes
wasteful
15
$317,000,000
least

It is estimated that over (1)____ per cent of all fires caused in this country are due to (2)____. Even in the forest where many fires are set by (3)____, over (4)____ per cent are caused by man. Forest fires cause our (5)____ annual fire loss. Our total loss from fires in 1933 was nearly (6)____. In that year a single forest fire in Washington burned an amount equal to (7)____ years of (8)____. Oil fires are very (9)____ and difficult to (10)____. Coal mine fires are also difficult to put out; one in Pennsylvania has been burning over (11)____ years. Besides man, (12)____, and (13)____ have been the causes of some of the world's most serious fires in (14)____.

PROBLEM TEST

Forest fires in this country are gradually doing less damage yearly.

Select from the list below the sentence or sentences that best complete the statement given above.

1. Because there are fewer thunder storms than there used to be.
2. Because the forest area is being cut off and there is less to burn.
3. Because forests are not worth as much as they used to be.
4. Because the federal and state governments have established more public camp grounds so that fewer fires are built in the forest by campers.
5. Because people have become better educated.

Match with the sentence or sentences above, those giving the best reasons for your answer.

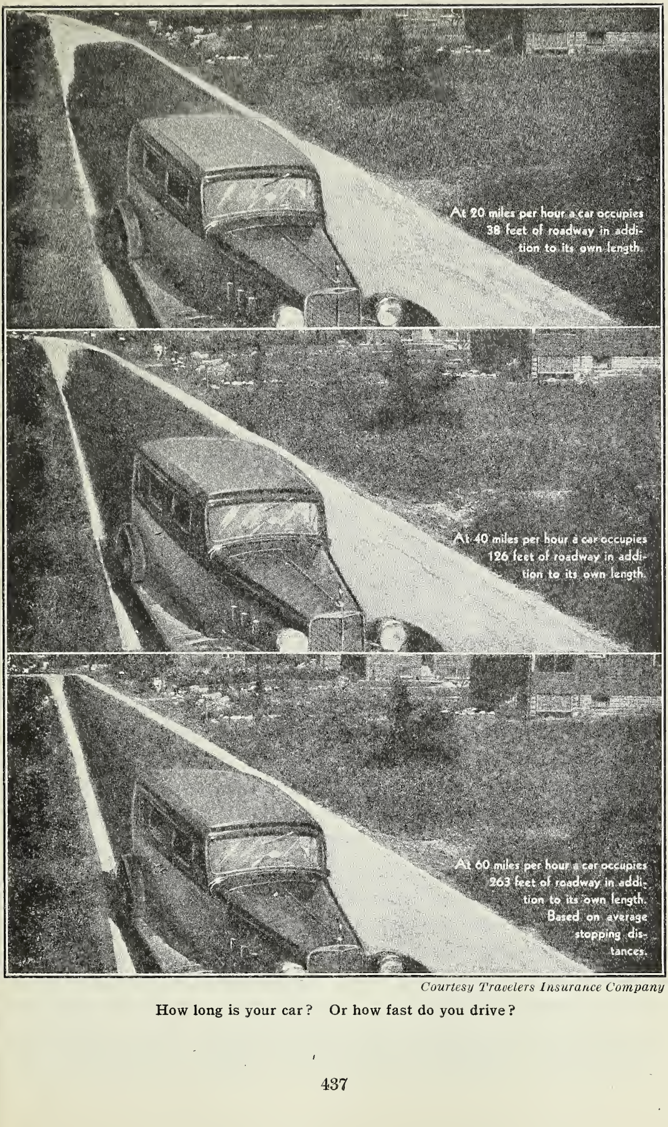
1. The average number of thunder storms remains the same from year to year.
2. Forests are being replanted and lumber companies are practicing reforestation.
3. The depression has lowered the price of lumber.
4. More people are using controlled public camp grounds each year.
5. Many agencies are educating people.

PROBLEM IV. WHAT CAN WE DO TO CUT DOWN LOSS OF LIFE FROM AUTOMOBILE ACCIDENTS?

This Is the Age of Speed. Someone has said that probably $\frac{9}{10}$ of all auto accidents are caused by people trying to save five minutes. As he puts it, "Five minutes a day will keep the ambulance away." It is certain that the death toll from automobile accidents is rising steadily. One reason for this is that cars go faster and have higher horsepower. A car going 40 miles per hour is four times as capable of doing damage as at 20 miles per hour. When going 60 miles per hour, it is nine times as capable of doing damage. At 20 miles an hour it takes about 38 feet to stop a car; at 40 miles about 126 feet; and at 60 miles an hour it takes about 263, based on average stopping distances. When you remember that since the beginning of 1930 to the beginning of 1934 there have been nearly 125,000 people killed and 4,000,000 people injured, it is evident that we ought to sit up and take notice. In a 10-year period the number of people killed by automobiles would exceed the total number of all soldiers killed in battle in the history of this country, and would be six times as great as our fatalities during the World War. The number of injured people would be fifty times that of our soldiers non-fatally wounded in action during the World War. During the last decade the record of deaths stands as follows:

1924	19,229	1929	30,858
1925	21,628	1930	32,540
1926	23,264	1931	33,346
1927	25,533	1932	29,196
1928	27,618	1933	29,900

In addition to the loss of life in 1933 there were 850,700 injured. The number of automobiles in use in 1927 was about 3 per cent less than the number used in 1933, but the death rate in 1933 increased 17 per cent over that of 1927. When we study the table of accidents on page 438, we see that about $\frac{2}{3}$ of these accidents were due to driving errors. Although the number of accidents from this cause accounted for about $\frac{1}{4}$ of all the mishaps, the fatalities comprised approximately $\frac{1}{3}$ of all the deaths from driving errors.


At 20 miles per hour a car occupies 38 feet of roadway in addition to its own length.
At 40 miles per hour a car occupies 126 feet of roadway in addition to its own length.
At 60 miles per hour a car occupies 263 feet of roadway in addition to its own length. Based on average stopping distances.

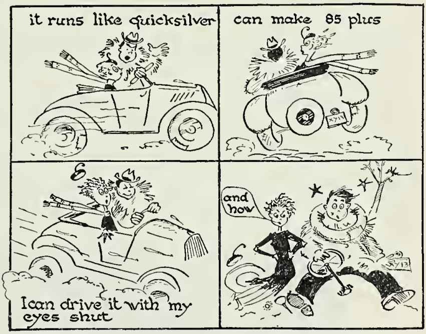
Courtesy Travelers Insurance Company

How long is your car? Or how fast do you drive?

	Number of Accidents	Per Cent	Persons Killed	Per Cent	Persons Injured	Per Cent
Exceeding speed limit	125,930	25.57	5,640	32.79	143,930	25.79
On wrong side of road	61,270	12.44	2,270	13.20	71,720	12.85
Did not have right-of-way .	118,400	24.04	2,320	13.49	143,650	25.74
Cutting in . . .	18,760	3.81	340	1.98	22,770	4.08
Passing standing street car . .	3,100	.63	110	.64	3,630	.65
Passing on curve or on hill . .	5,420	1.10	140	.81	5,530	.99
Passing on wrong side	7,880	1.60	210	1.22	9,430	1.69
Failed to signal and improper signaling . . .	35,760	7.26	380	2.21	44,480	7.97
Car ran away — no driver . .	3,740	.76	210	1.22	3,960	.71
Drove off roadway	58,900	11.96	3,260	18.95	53,240	9.54
Reckless driving .	31,670	6.43	1,520	8.84	30,090	5.39
Miscellaneous . .	21,670	4.40	800	4.65	25,670	4.60
Total . . .	492,500	100.00	17,200	100.00	558,100	100.00

This indicates very clearly that the speed is a very important factor. To drive too fast for the conditions is to increase the probability of death in the event of an accident. Figures on weather conditions show us that contrary to common belief, fog, rain, and snow are not as responsible for accidents as we think. On wet or icy surfaces, drivers have much difficulty in keeping their cars under control and therefore take greater care. When road conditions are safe, drivers are more careless and hence we have more accidents. There are other figures that tell us that *speed* is responsible for many accidents. For example, on Saturdays we have the greatest number of fatal accidents, while on Sundays there are not quite so many, although Saturday and Sunday combined show a death rate 20 per cent greater than on the rest of the week. What is the reason for the higher death rate on Saturday? Probably because the people are hurrying to get away, are going faster, and perhaps take less care. Darkness is another factor in auto accidents. It was found during 1933 that the death rate per accident was 43.5 per cent worse during the hours of darkness than during the hours of daylight, and there were more accidents proportionately during the hours of darkness than during the hours of daylight. Good street lighting helps to control this to a very large degree.

Does the Age Have Anything to Do with Careless Driving? It looks as if it did. According to a graph made by one of the accident insurance companies, the accident death rates in age group 15–19 and 20–24 far exceed those for older people. What does this mean? It probably means that young people when they drive are not so apt to have their minds on driving as do older people. They do not pay attention to their job; they are talking, showing off, and perhaps in some cases have been drinking. It is not the beginner in driving that is responsible for the most accidents; on the contrary, it is the driver who has had experience of a year or more who gets into the most trouble. Young people should remember that driving is a serious business. They must realize that passing cars on curves, trying to get ahead of the other fellow, jumping the signal at intersections, and numerous other tricks that young and active people have are dangerous in the long run.



What story does this cartoon tell? How would you have enjoyed the ride?

Automobiles and Safety. Manufacturers of automobiles have produced a nearly mechanically perfect car, for less than 5 per cent of all automobile accidents are due to defects and most of these are in old cars. Glaring headlights are a danger, but many states have introduced laws against this hazard, and improvements in the intensity and direction of the lights are being made constantly.

Another hazard comes from the use of old tires. We often buy new tires and place them on the rear wheels where the most wear is. If old tires are left on the front wheels, there is a possibility of one of them blowing out when the car is being driven at a rapid rate. If this happens, the car is almost certain to be thrown to one side, with a possibility of a dangerous accident.

Automobile Driver. Probably the most serious hazard to pedestrians and to those riding is the automobile driver. In a study made in Connecticut, it was found that out of 25,000 accidents investigated in 1926, 71 per cent were the fault of the driver of the car; 20 per cent were the fault of other persons; 3⅓ per cent were caused by defective cars or equipment, and 4⅔ per cent were due to other causes.

Deaths to Pedestrians. During 1933 45 per cent of the total 29,900 deaths from automobile accidents were pedestrians, and 82 per cent of the accidents occurred in rural districts as against 18 per cent in the cities. This means that in controlled traffic where pedestrians have stop and go lights to help them, the actual danger is nowhere nearly as great as on the open road. A great many people are killed walking on highways because they insist on

Galloway

A busy traffic intersection. In order to cross the street with safety wait for the green light.

walking on the same side that the car is going. Part of our safety education ought to be directed to getting people to walk facing the oncoming cars. It is almost impossible in the dark for a driver, no matter how good he is, to avoid hitting a pedestrian on the open road in front of the car. If you study the table, you will see that most of the city accidents are brought about by the people crossing between intersections or against the signals, or on streets where there are no signals. While many accidents to children come from their walking out from behind a parked car or playing in the streets.

ACTIONS OF PEDESTRIANS RESULTING IN PERSONS KILLED AND INJURED IN 1933

Crossing at Intersection	Pedestrians in Accidents	Per Cent	Pedestrians Killed	Per Cent	Pedestrians Injured	Per Cent
With signal	9,320	3.38	190	1.41	9,130	3.48
Against signal	29,680	10.76	810	6.03	28,870	11.01
No signal	41,460	15.04	1,650	12.28	39,810	15.18
Diagonally	4,240	1.54	360	2.68	3,880	1.48
Crossing between intersections	67,290	24.40	3,320	24.70	63.970	24.39
Waiting for or getting on or off street car	3,110	1.13	70	.52	3,040	1.16
Standing on safety aisle	820	.30	30	.22	790	.30
Getting on or off other vehicle	3,390	1.23	270	2.01	3,120	1.19
Children playing in the street	49,780	18.05	1,680	12.50	48,100	18.34
On work in roadway	5,600	2.03	330	2.46	5,270	2.01
Riding or hitching on vehicle	4,880	1.77	290	2.16	4,590	1.75
Coming from behind parked car	35,010	12.70	1,460	10.86	33,550	12.79
Walking on rural highway	10,060	3.65	2,250	16.74	7,810	2.98
Not on roadway	5,400	1.96	230	1.71	5,170	1.97
Miscellaneous	5,670	2.06	500	3.72	5,170	1.97
TOTAL	275,710	100.00	13,440	100.00	262,270	100.00

The Pedestrian. The person on foot has certain rights on the road, but should at all times be watchful of the man in the machine. More than half the accidents in which pedestrians are injured happen to children who are thoughtless in crossing streets. One estimate indicates that out of 100 pedestrians killed by automobiles, 65 were crossing the street carelessly, 18 stepped out from behind some object, 8 were intoxicated, 6 confused, and 3 were getting on or off a street car. These figures indicate that no one should take chances in dodging streams of rapidly moving traffic.

Uniform Traffic Control. Much confusion results at the present time because of lack of uniform traffic control. Different states have different rules and different signals. In New York State, in 1927, there were nine different methods of making turns at intersections where traffic-control signals regulated traffic, but this situation is improved at present. The painting of lines, arrows, and symbols on the pavement is a great help to the motorist, and if in addition we had uniform traffic regulations, many accidents would be avoided.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

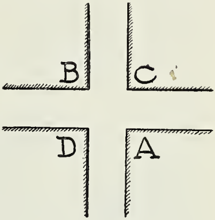
exceeding
Saturday
way
12
save
90
720
lose
damage
daylight
speed
8
time
16
brakes
130
38
after
4
driver
right
260
night
480

This is the age of (1)____ and a very large percentage of our auto accidents are caused by people trying to (2)____ a little (3)____. At 20 miles an hour a car can stop in (4)____ feet if the (5)____ are in good condition, but if the car is going 60 miles an hour, it takes over (6)____ feet to stop it. A car going 40 miles an hour is capable of doing (7)____ times as much (8)____ as one at 20. The greatest number of accidents comes from (9)____ the (10)____ limit. Not having (11)____ of (12)____ caused the next largest number. More accidents occur on (13)____ than any other day and more accidents proportionately occur (14)____ dark than in the (15)____. Most accidents occur because of the fault of the (16)____ and not of the car.

PROBLEM TEST

You are at point *A* and are in a great hurry to get to point *B*. There is heavy traffic, no traffic lights and no officers around. Which of the following things would you do and why?

1. I would cut across, taking the most direct route from *A* to *B*, and dodge the cars.
2. I would go from *A* to *D* and from *D* to *B* without waiting for traffic to stop.
3. I would go from *A* to *C* and then from *C* to *B* but would look both ways and wait for traffic to halt.



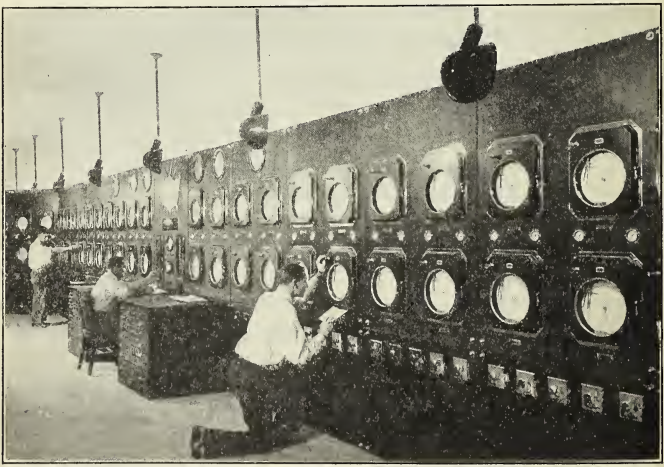
Reasons

1. If I cut across I go the shortest way.
2. If I go from *A* to *C* and *C* to *B*, I can take the streets one at a time.
3. If I wait for the traffic to halt on each street as I go across, my chances of being hit are less.

PROBLEM V. HOW IS CONSERVATION OF LIFE IN INDUSTRY BEING EFFECTED?

The Early Days of Factory Industry. About the beginning of the 19th century along with the invention of the power loom and the spinning jenny the modern factory came into existence. Very soon industry began making demands on workers which had not been made in days before machinery was used. The work in factories has become more and more automatic as machine after machine has been invented to do the work that man used to do himself. As profit was the main reason for the existence of the factory, it is little wonder that the health of the workmen was not much thought of in the early days of factory labor. Factory hands had to work under very insanitary conditions for long hours and often at dangerous kinds of work. Children were employed for small wages to do some of the easier kinds of work, and sometimes forced to work 10 to 12 hours a day.

What Are Dangerous Occupations? Today all is changed and child labor has finally been abolished in this country. Children at least have now an opportunity to get schooling and recreation that they used to be deprived of. But there is much still to be done for the worker. There are a number of very dangerous occupations, such as those in which poisons are used, particularly lead, which is used in over 100 processes or trades. Phosphorus, used in the making of matches, used to be a very serious menace, but laws have been passed restricting its use. Recently some girl workers in a factory where luminous watch dials were made suffered from radium poisoning, which was contracted through the mouth. These workers had carelessly used their lips to point the brushes with which they painted the dials. The radium, being such an active substance even in this weak preparation, caused the flesh to be eaten away. The dusty trades, such as stone cutting, coal mining, or the cement industry; work in which very high temperatures are necessary, such as that of the firing or working with the blast furnace, and many others are also dangerous. Besides those mentioned, we have occupations in which sharp cutting instruments are used, as in sawmills or furniture factories, occupations where the workers are exposed to poisonous

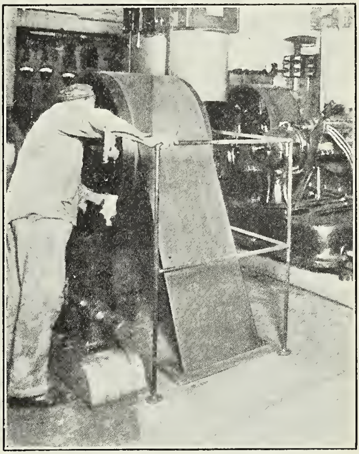


National Broadcasting Co.

The largest air-conditioning plant in the world in the RKO building at Radio City, New York.

fumes or gases, and occupations which use compressed air, such as making tunnels, deep-sea diving, or laying foundations in caissons under water. There have been listed over 675 different occupations which are more or less dangerous.

What Is Being Done to Reduce Danger? Fatigue, both physical and mental, has long been one of the most serious health and accident hazards. It has been found in most industries that the curves of greatest production, greatest fatigue, and greatest number of accidents closely coincide. But under present conditions of labor, fatigue is nearly eliminated in most occupations by shortened hours of labor. In trades which are conducive to tuberculosis or throat and nose affections, blowers are installed to carry off the dust, and in many states the worker is required to wear a protective mask. Where grinding is done, the wheels are kept wet and protected by shields; fans and mechanical ventilating systems are used where poisonous fumes and dusts occur. On the other hand, in mines, cement quarries, sand blasting, stone-cutting plants, and in many occupations dangerous dust forms a serious menace to health.



A protected belt in a modern factory.

Some workers, such as welders, glass blowers, or furnace workers, are exposed to extremes of light or heat. These men are protected by goggles or protectors. On the other hand, many workers who do close work, such as watch making, engraving, or embroidery, ruin their eyes because of not enough illumination. Good illumination not only conserves eyes, but gives more efficiency in production. In industries where the worker is exposed to high temperatures, special ventilation is necessary, as well as plenty of opportunity to rest and bathe. One of the most dangerous of all occupations is that of working under compressed air.

Accidents in Industry. Partly as a result of these dangerous occupations and partly because workers are careless, we have over 20,000 fatal accidents every year, and over 260,000 serious injuries in industry, while the total number of minor injuries is about 1,500,000. The five most dangerous occupations from the standpoint of accidents are, in order, (1) metal mining; (2) coal mining; (3) fisheries; (4) stevedoring; and (5) electrical and coke oven industries. In many industries, especially modern factories, the worker is well safeguarded. But the care taken of employees avails little unless the workers themselves are careful. Over half of all industrial accidents are due to the carelessness of the workmen. Safety-first campaigns have done a good deal in reducing injury, especially in large corporations where a campaign has been carried on over long periods of time. The welfare work now being done in many large factories reduces the chances of accident because it helps to prevent illness and fatigue. But we still have two large factors which are controlled by the worker: carelessness and intemperance. Without control of these factors, we shall continue to have many unnecessary deaths in industry no matter how much science does to protect the worker.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

working
temperate
safer
careless
protective
farming
unhygienic
poisons
short
industries
goggles
mining
intemperate
careful
long
poisonous
sleeping
laws
necessary
blowers
compressed
unsafe
dusty
safe

When factories first came into existence, men had to work (1)____ hours and under very (2)____ conditions. Today (3)____ protect workmen and have made the (4)____ conditions in most factories (5)____. But there are still some (6)____ that are dangerous, such as (7)____ and (8)____ trades, industries that use (9)____ or (10)____ gases, and particularly work that has to be done in (11)____ air.

Much has been done to make these occupations (12)____, such as the introduction of (13)____, fans, (14)____ masks and (15)____ clothing. But there will always be more accidents and deaths than (16)____ because men are (17)____ and because some are (18)____.

PROBLEM TEST

In a certain factory storage batteries are manufactured. Peroxide of lead is one of the substances used in the process. The workers are provided with respirators and gloves.

Which of the following statements give the best reason for this provision?

1. Gloves will keep the hands clean and the respirators will keep the workers from getting the unpleasant odors.
2. The law says that these articles must be provided in all factories.
3. Peroxide of lead gives off poisonous fumes in the process and lead is a poison that can be absorbed through the skin.
4. Lead is bad for the complexion, so the hands and face of the worker are protected.
5. In making storage batteries, the oxide of lead is mixed with litharge and this causes dirt and an unpleasant odor.

PROBLEM VI. HUMAN CONSERVATION, EFFICIENCY AND ALCOHOL

In the previous problems of this unit we have seen some of the ways in which conservation is being practiced in this country. But the most important conservation of all is that of human life. We have already seen some ways in which the life span is being gradually lengthened and we shall learn more about some of the government agencies that help to do this. There is, however, one very serious drawback to the human conservation problem. It comes out of the fact that there are a certain number of individuals who, in spite of all that can be done to help them, will drink to excess. This fact in itself accounts to a very great extent for the death rate from accidents in this country. While we are lowering the death rate from almost every other cause, we find a larger and larger number of people each year dying before their time because of accidents. And when we come to analyze the causes carefully, we are very likely to find that alcohol had a part in it.

Deaths from "Drunk Driving." The serious side to "drunk driving" is that people who drink may not be legally drunk, for if they were, they probably could not drive at all. But they are sufficiently under the influence of alcohol so that they may not react as quickly as they normally could, or their vision might be slightly impaired so that they could not see traffic signals as well as usual. When physicians examine persons arrested for drunk driving, the slow mental reactions and lack of muscular co-ordination are almost always found, although the driver may not actually be drunk. In other words, the accident happened because alcohol replaced caution with recklessness and dulled the brain so that the reaction time was lengthened enough to turn a close shave into an accident. The use of alcohol by the locomotive engineer is prohibited by law. Why not prohibit its use by the driver of a car? As one writer puts it: "The margin between safe and unsafe driving is too narrow to permit drinking."

FATAL MOTOR VEHICLE ACCIDENTS CAUSED BY LIQUOR IN MASSACHUSETTS

Year	Total Killed All Classes	Liquor Cases	Killed in Liquor Cases	Per Cent Killed in Liquor Cases
1922	522	42	49	9.3
1923	578	46	62	10.7
1924	709	43	48	6.7
1925	755	56	63	8.3
1926	705	41	46	6.5
1927	693	40	57	8.3
1928	715	51	51	7.1
1929	777	52	52	6.6
1930	795	76	81	10.1
1931	793	60	68	8.5
1932	768	74	87	11.3
1933	769	64	69	8.1
1934	921			

What the Newspapers Have to Say about Drunk Driving. The following clippings from representative newspapers in different parts of the country show what the public has to say about drunk driving: *Santa Barbara, California, News:* "The drunk driver is a potential murderer and he should be driven from the road, deprived of his car, and kept in a cell until sober thoughts displace the distorted ones that were in his mind while driving the car down the highway." *Denver, Colorado, Post:* "We have many times the automobiles now than before prohibition. . . . Booze and gasoline make just as deadly a mixture when the sale of liquor is legal as when it is illegal. Drastic steps will have to be taken to prevent persons under the influence of liquor from driving." *Woonsocket, Rhode Island, Call:* "Gasoline and liquor do not mix. All citizens have a right to expect protection from such a menace. This problem of the drunk driver is one which ought and must receive immediate attention." *New York Times:* "In the first ten months of 1933 arrests for intoxication totaled 2516; in the corresponding months of 1934 there were 3118. In the 1933 period 1325 persons were arrested on the combined charge of drunkenness and disorderly conduct; in the 1934 period the total was 1550. In 1933 arrests for operation of a vehicle while intoxicated were 651; this year they were 689. Total arrests involving drunkenness: 1933, 4492; 1934, 5357." In many states the law with reference to drunk driving is now being interpreted to mean that anyone under the influence of liquor is considered a non-safe driver. Until we stop drunk driving, we still have a very serious unchecked menace to public safety.

Alcohol and Industrial Accidents. The past few years have seen great advances in the protection of the industrial worker. Not only have hours been shortened and child labor prohibited, but the hazards of the factory and shop have been largely done away with. This has been brought about by a combination of laws and the realization on the part of the employers that efficiency will suffer if the employees suffer. But much of the benefit which comes from such protection is lost because we cannot protect the worker against himself. The unsteady hand and inaccurate eye of the drinker combined with his slightly longer reaction time again and again results in accidents, and with this a loss in efficiency. Raw materials may be lost, machines ruined, and what is far worse, a workman maimed or perhaps killed. Employers can refuse to employ habitual drunkards, but they cannot refuse to employ moderate drinkers. But such people are the very ones who seem to cause the bulk of our industrial accidents. The accident rate was reduced 54 per cent in the steel mills in Coatesville, Pennsylvania, during the first six months after the prohibition amendment was put into force, and the first dry year in one of the largest copper mining and smelting companies in Arizona saw the accident rate reduced 83 per cent. These cases with hundreds of others prove that alcohol is the big cause of industrial accidents. It has been estimated that 8000 deaths, 100,000 severe injuries, and 800,000 slight injuries were due to alcohol each year prior to prohibition, allowing one third of all accidents as being due to drink.

The Economic Waste of Drink. Another side of conservation is seen in saving. Money which is put out at interest is doing good and may be used by people for radio sets, clothes, cars, necessities, or luxuries. But if the money is spent in drink, it is lost to the worker and his family. It is estimated that at the time we entered the World War, the American people were spending about $2,000,000,000 a year for alcoholic drinks. We found during the early years of prohibition that a very large amount of that $2,000,000,000 went into savings and more comforts for the home. Savings per individual in the United States increased from $90 before the war to $188 for the years 1921–1925. Industrial insurance increased 250 per cent in that same period. Of course it was not entirely prohibition that caused this, for many complex factors entered into the picture, but undoubtedly the fact that

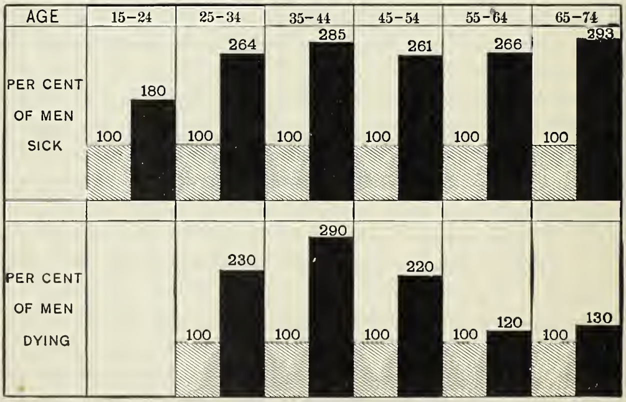
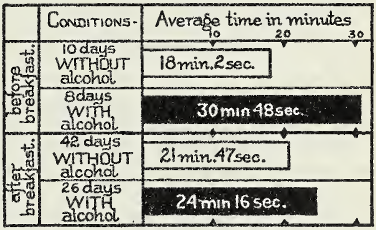


Table to show a comparison of chances of illness and death in drinkers and non-drinkers. Solid black, drinkers. (From German sources.)

people could not easily get liquor, added to the fact that many others believed in the prohibition law, played a very important part in the economic welfare of workers during this period. President Hoover in his report as Secretary of the Department of Commerce in 1925 said: "There is no question that prohibition is making America more productive." He estimated that the individual worker showed a 10 per cent increase in efficiency. In the new economic life that faces us today, with many unemployed and fewer places to fill, it is natural that only the most efficient will secure employment. That will mean that the others will have to be taken care of by some means of state or national aid, and that the money to pay for this must be raised by taxation from those who do work. Who can tell what proportion of this load is due to alcohol?

With the ending of prohibition the use of liquors has increased. There are today thousands of children who have weak bodies from lack of proper food and clothing living in unhealthful homes. The reason for this shameful condition is that many fathers — slaves to alcohol — spend too much of their earnings to satisfy their craving for liquor.

Alcohol and the Length of Life. The largest economic loss comes from the shortening of life due to alcohol. We have ample proof taken from many sources that the human span of life may be greatly shortened by drinking to excess. The fact that not only does the alcohol poison the human cells, but that it also affects the kidneys, heart, blood vessels, liver, and digestive tract, makes it evident that it is a dangerous cumulative poison. And what is worse, experiments seem to show that the effects of alcohol may be handed down to the next generation, and that children of drunkards are likely to be handicapped by ill health. These facts more than any others prove that alcohol plays a most important part in offsetting all that science is doing to prolong and conserve human life. What are you going to do about it?



The effect of alcohol on ability to do mental work.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

poor
safeguarded
lost
economically
add
motor
lives
live
die
death
length
railroad
brevity
drinking
offspring
accidents
driving
liver
subtract
lost
alcohol
safety
life
water

In spite of all science is doing to (1)____ to the (2)____ of human (3)____, (4)____ is to a large extent undoing this good. Drunk (5)____ is causing an increase in (6)____ accidents, thus wasting many (7)____ that would be (8)____ valuable. Then in industry, although man has (9)____ the workers with many (10)____ devices, he cannot keep him from (11)____ and thus having (12)____. Economic waste occurs with (13)____, for the money which would otherwise go toward making the home more comfortable is (14)____. But the greatest economic loss comes through the earlier (15)____ of the drinkers and the fact that their (16)____ are often weakened or (17)____ young. (18)____ certainly costs our nation too much.

ESSAY TEST

Harry Tells of the Economic Losses from Alcohol

Read carefully and critically. List errors and suggest corrections.

Until I read a little and thought something about the economic losses caused by drink, I had no idea of what it costs this nation a year. In the first place, the money cost of drinking alone is probably $2,000,000,000 a year. That would go quite a way toward balancing our national budget and it is a lot more than goes into our public schools. Then it plays a big part in auto and industrial accidents. We can only guess how much, although figures give at least two thirds of all deaths and accidents to this cause. Nobody knows how much economic waste there is through poor workmanship of drinkers, but it must amount into the billions. Of course the worst thing of all is that it causes so many people to die while they are still quite young, and that its effects may be handed down to the children born of drinking parents so that these innocent victims may be weak and sickly. They never will have a fair chance and it is not their fault. I certainly will do my best to fight this drink evil, for it surely looks bad to me.

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned. The following generalizations will help you in getting the big ideas:

1. Natural resources of minerals, fuels, and living things should be conserved.
2. Floods are caused by deforestation.
3. Erosion is prevented by forests.
4. Many imported insect pests do much damage to forest trees and to crops.
5. The United States and state governments are restocking many waters with fish.
6. The yearly fire losses in this country are much greater than they need to be.
7. Automobile accidents are increasing, thus the toll in killed and injured is enormous.
8. Conservation of life in industry is carried out by means of safety devices, safety-first campaigns, and improved ventilation and lighting.
9. Alcohol is a serious factor in the cause of fatal accidents.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT, *write the numbers of all statements you believe are true. In another column under* INCORRECT, *write numbers of untrue statements. Your grade = right answers × 2.*

I. **Conservation of oil and mineral resources may be practiced:** (1) by more efficient mining; (2) by storing large quantities of oil until it is used; (3) by efficient utilization of wastes; (4) by not allowing anyone to exploit public property; (5) by not driving the auto too fast.

II. **Conservation of water:** (6) is seen when man utilizes the flow of a stream for power; (7) means more farming in the White and Green mountains; (8) is now seen at the Boulder Dam site; (9) is accomplished through the use of reservoirs; (10) may mean the conservation of land as well.

III. **Conservation of forests is necessary:** (11) in order to protect and regulate our water supply; (12) to give us a place to camp; (13) to conserve birds and wild life; (14) to prevent insects from doing harm; (15) to maintain our supply of lumber.

IV. **Forest protection and conservation:** (16) result in more erosion and more run-off; (17) cause less erosion and less run-off; (18) cause devastating floods; (19) are part of the work of the Citizens Conservation Corps; (20) can only be brought about by not cutting our forests.

V. **Conservation of natural resources implies:** (21) control of harmful insects; (22) protection of people from accidents; (23) economic use of our coal, oil, lumber, fish, etc.; (24) a knowledge of first aid; (25) placing a high tax on gasoline in order to cut down its use.

VI. **Among the living things that should be protected are:** (26) the Japanese beetle for its usefulness; (27) the gypsy moth for its beauty; (28) the Calosoma beetle for its habits; (29) birds because of their habits; (30) game fish for their use as food.

VII. **Automobile accidents are due chiefly to:** (31) bad roads; (32) tire blowouts; (33) inattention on the part of the driver; (34) intoxication; (35) carelessness on the part of the pedestrian.

VIII. **Most fatalities today come from:** (36) traffic accidents; (37) industrial accidents; (38) drowning; (39) falls; (40) carbon monoxide poisoning.

IX. **Fire losses in this country can be reduced by:** (41) using no wooden shingles on buildings; (42) preventing smoking in forest areas; (43) using safety matches; (44) avoiding careless use of fire in the home; (45) having more fire insurance.

X. **The use of alcohol prevents conservation by:** (46) causing automobile accidents; (47) acting as a narcotic poison; (48) slowing up reaction time in the factories; (49) using up grain; (50) shortening the human life span.

PRACTICAL PROBLEMS

1. Mary, driving her father's car, loses control on a downgrade because her gear shift is in neutral. What must she do to regain control of the car and save her passengers?

2. Charles, in warming up the car in the closed garage on a cold morning, feels suddenly ill. What should he do?

3. Your car stops suddenly on a dark night. You have no flash light but you do have a supply of matches. How could you find out if the gas tank is empty?

4. You are in the woods, a wind is blowing and your campfire goes out of hand and starts a brush fire. What should you do?

5. An unknown (to you) insect pest is destroying your garden. What can you do about it?

6. Prepare a score card for grading the efficiency of a fire department. Then score your community fire department.

7. Classify in order of importance ten important natural resources in your state.

8. In what ways can you safeguard little children against risks they take from fire? Your school? Your community?

9. Copy the table given below on a sheet of paper the size for your workbook. Fill in the data suggested. For source material use *International Yearbook, World Almanac, The Waste of Fire,* by F. H. Wentworth, *Safety Engineering,* your state research bureau.

	United States	Your State	Your Community
Population last year			
Fire loss last year			
Loss per capita			

How does your community compare with your state? With the rest of the United States?

10. Study the table and chart on pages 2 and 3 of *Safety Education in the Secondary School,* by Stack, and try to compare it with your local figures. Make a block graph chart to illustrate.

LIBRARY RESEARCH READING

1. Look up some of the following interesting topics in *Forests and Mankind,* by Pack and Gill, the Macmillan Company:
    - *a.* What is forestry and how does the forester work?
    - *b.* Where does our paper come from?
    - *c.* Fire, the great destroyer.
2. Write on the topic: A fire I once saw.
3. You will find Hill, C. T., *Fighting a Fire,* or O'Higgins, H. F., *Smoke Eaters,* very interesting reading. What other books can you add to your list?

LEISURE TIME ACTIVITIES

1. Make a list of all the auto accidents mentioned for one month in the paper that you take and classify them in a tabular form which

you will devise. Can you get local statistics from the Department of Motor Vehicles in your state?

2. Make a list of the methods of traffic control in your city, town, or community. Compare them with a list made in some other state or community.

3. Make a list of all the deaths within one month from carbon monoxide poisoning which you read about in the daily papers.

4. What fire and accident hazards do you have in your home? Your school? What suggestions can you make for removing them?

5. Collect from your local newspaper for one week accounts of fires. Paste these in your notebook. Study them to determine: causes, losses, how extinguished, and whether or not they could have been prevented by reasonable care.

6. Find out the acreage your state has in national forest reserve. In national parks. In state forests.

7. What protection does your state give to birds? What can you personally do for bird protection and conservation?

8. Do you know what protection various wild flowers have in your state? What protection is given to various wild animals in your state?

SCIENCE CLUB ACTIVITIES

1. Have a meeting devoted to safety first or to the discussion of the following statement: "To put out a fire when it has begun to burn is good, to keep it from starting is better."

2. Make a survey of your community to see what dangerous occupations exist there and what is being done to safeguard the workers in these occupations.

3. Make a trip to some large industrial plant and report to the club on the safeguards used for protection against accidents and fatigue.

4. Debate the question: Resolved that the main purpose of a fire department is not to put out fires but to prevent them.

5. Make a book list or article list on the topic of conservation and post it on the bulletin board.

REFERENCE READING

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Fisher, E. F., *Resources and Industries of the United States.* Ginn and Co., 1928.

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Pack, C. L., *The School Book of Forestry.* American Tree Asso., 1922. Uses of trees, pp. 41–53; fire, pp. 53–64; insects and diseases, pp. 64–73; forestry and national forests, pp. 73–109; conservation, pp. 109–159.

Pack, C. L., and Gill, T., *Forests and Mankind.* The Macmillan Co., 1921. Chapters V, VI, VII, X, XI, XV.

Payne, E. G., *We and Our Health.* American Viewpoint Society, '24. Safety in the home, pp. 81–87; safety in the streets, pp. 87–93; safety in other places, pp. 93–97; first aid, pp. 102–115.

Rolfe, M. A., *Our National Parks.* Benj. H. Sanborn & Co., 1927–1928. Volumes I and II.

Stack, H. J., *Safety Education in the Secondary Schools.* National Bureau of Casualty & Surety Underwriters, New York, 1929. Teacher and student reference.

Survey Questions

Have you ever tried any experiments in breeding plants or animals? If so, tell the class about them.

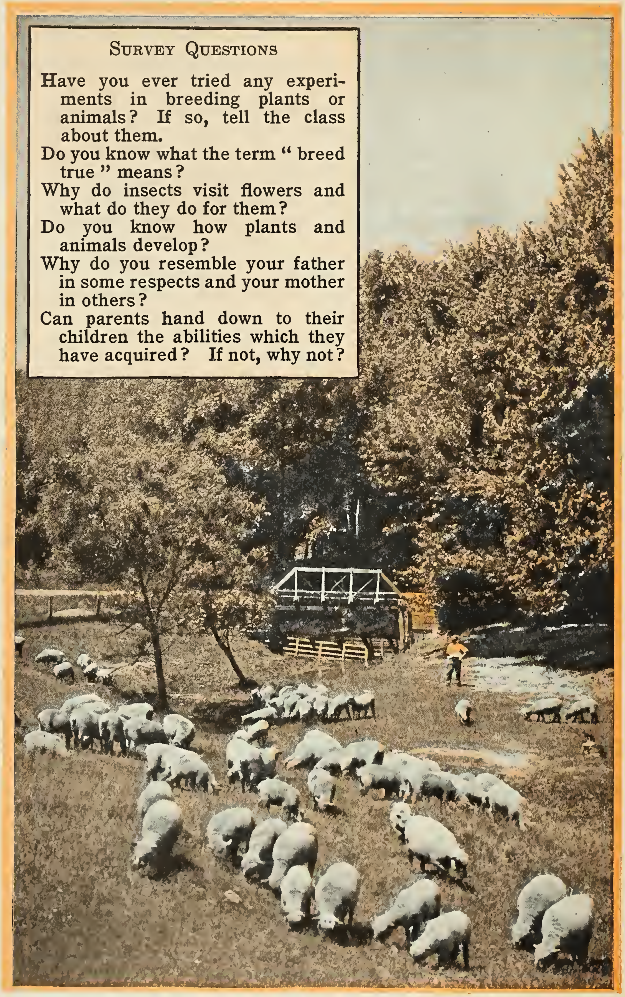
Do you know what the term " breed true " means?

Why do insects visit flowers and what do they do for them?

Do you know how plants and animals develop?

Why do you resemble your father in some respects and your mother in others?

Can parents hand down to their children the abilities which they have acquired? If not, why not?



UNIT XIV

THE IMPROVEMENT OF LIVING THINGS

PREVIEW

It is pretty much of a guess when primitive man first settled down and began to cultivate and domesticate wild plants and animals. The Swiss lake dwellings, remains of which have been discovered on the shores of certain Swiss lakes, date back to the stone and bronze ages, perhaps as far back as 10,000 years before Christ. These show that even in the stone age oats, barley, millet, flax, and some fruits such as the pear, apple, and grape were probably cultivated. No domestic animals appear until the bronze age, when the remains of sheep, cattle, swine, and dogs are found. In America corn must have been cultivated at a very early period, for corn has been found with mummies in Peru buried many feet underground. Great terraced cornfields have been found that date back to the time of the Incas. We know it had long been cultivated by the North American Indians, for when Jacques Cartier first saw the site of the present city of Montreal, he found there a village surrounded with cornfields.

Since all animals which he hunted depended upon grains, and wild grains are species of grasses, we can guess that the first farmers lived in fertile valleys where grass and game were plentiful, that they found this a good place to settle in. They probably also found they could keep and store the hard wild grains, so a permanent settlement was established where wild grains could be stored for winter use. Along with this might have come domestication of wild horses, hogs, or oxen. Then the breeding of plants and animals might have begun.

For many centuries, men interested in breeding plants and animals have noticed two important facts concerning them, namely: in both plants and animals the offspring of the same species are alike and yet each is slightly different from the others produced. This likeness of offspring to parent is due to what we call *heredity*. But if you were to examine the plants more closely, you would find that each one is slightly different from its neighbor. This tendency among plants and animals to differ is called *variation*.

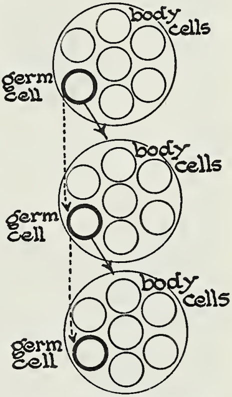
Until the middle of the last century breeders used more or less haphazard methods in working for new varieties of plants and animals. Then Charles Darwin, a great English scientist, began to make a special study of heredity and variation. He noticed that in nature the variations which seem to fit an organism for life in its own environment were the ones handed down from one generation to another. Darwin thought that if nature made use of favorable variations, man could select favorable variations also, and by care, breed for those characteristics which he desired. Such artificial selection is seen in everyday farming. Then came the discovery of new laws of heredity by Gregor Mendel and their application by hundreds of workers in the United States Department of Agriculture, in various state departments of agriculture, and by many private agencies on experimental farms. The result already has been to add millions of dollars to the pockets of the farmers of this country and numbers of new and delicious fruits and vegetables as well as more productive grainfields and better livestock.

Before we go on to the further study of the unit, let us look back to see if there are any science principles or generalizations on which we can build our science in this unit. Some of these are:

1. The living things found in a given area depend upon the environment.
2. Certain plants and animals are always associated with each other.
3. Living things depend upon each other.
4. Under certain conditions, green plants manufacture food.
5. Living things come from other living things.
6. Living things are made up of cells.
7. There is a balance in nature.
8. Man may upset this balance.
9. Man exerts control over his environment which may result in making a new balance.

PROBLEM I. HOW DO PLANTS AND ANIMALS PRODUCE OTHERS?

What Causes Plants and Animals to Form Others Like Themselves? We have already learned that plants and animals are made of cells. These cells may be placed in two groups, the ordinary *body* cells which give rise to stems, leaves, and roots of plants or to the flesh, bone, and blood of animals, and another kind of cells known as the *sex* or *germ* cells. The latter are set apart at a very early stage in the life of the plant or animal and are believed to be the bearers of what we call *hereditary qualities*, or characters. It has been pretty well determined by means of careful experiments that tiny structures called *chromosomes*, formed within the nuclei of the sex cells, contain the *determiners* of the qualities which are passed from parent to offspring. In plants, these sex cells are found in the flower contained in the ovules and the pollen grains. In animals they are called *eggs* (ova) or female sex cells, and *sperms* or male sex cells.



What does this diagram illustrate?

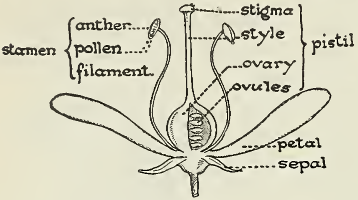
In our earlier study we have learned that flowers give rise to fruits. We shall now see why this happens.

Demonstration 1. To Learn the Structure and Use of the Parts of a Flower.

Materials. Any large flower such as the apple blossom, tiger lily; hand lens.

Observations. Notice that the flower is built with the parts in whorls or circles. How many parts are in the outermost circle? Of what color are they? They are called *sepals*. Collectively they make up the *calyx*. The parts in the next circle are called *petals*. Do they have color? Together they form the *corolla*. Notice the little knobbed structures next in order. They are called *stamens*. The stalk is called the *filament;* the knob, the *anther*. The yellow dust is *pollen*. Use a lens and see how the pollen gets out of the anther.

The middle part of the flower is called the *pistil.* The enlarged base is the *ovary;* the stalk is the *style;* the tip, which is sticky, is the *stigma.* Pollen will grow on the stigma. Cut a cross section through the ovary. The little structures inside are called *ovules.* Within each ovule is an egg cell which is too small to be seen without a microscope. This egg cell under certain conditions will develop into a baby plant or embryo. How might pollen get from the stamens to the ovule?



Conclusions. Which parts of the flower are necessary for the production of seeds? Which are called the *essential organs?* Which parts are they?

The Use of the Essential Organs. In flowers the stamens produce the sperm cells and the ovary produces the egg cells. Under certain conditions a pollen grain containing a sperm cell is deposited on the end of the pistil in the same flower or on a pistil of another flower of the same kind. Here it develops a long hollow tube through which the sperm cell reaches the ovary and unites with an egg cell, causing that egg cell to develop into a baby plant.

Demonstration 2. Cross-Pollination in Flowers.

Observations. Are flowers being visited by insects? If so, by what insects? Do bees visit flowers of one kind or of different kinds in order? Make a careful study of this with the bee, with the butterfly, and with other insects.

Do insects seem to know color? Do they seem to prefer one color to another? Can you discover any means by which the flowers might attract an insect? Insects can probably smell as well as see and taste.

Do you find any peculiar shapes in flowers which seem to offer a resting place for insects? If so, does the pollen from such flowers become attached to any part of the insect? Catch two or three different insects. Use a hand lens to see if any pollen is clinging to any part of their bodies. Could this pollen be carried from one flower to another of the same kind?

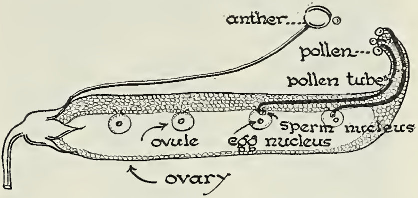
Conclusions. What do insects get from flowers? What do insects give to flowers? How might this be of use to plants?

Cross-Pollination. Pollen will germinate on flowers of the same kind on which it grew, and rarely on those which are nearly related to it. When bees are at work in the garden, you will usually find them going from one flower to another of the same kind, often visiting several in the same flower cluster. The bee, when it takes pollen on its hairy legs and body from the stamens of one flower and then visits another flower of the same kind, transfers the pollen grains to the stigma of the second flower, where they germinate. This process is called *cross-pollination.*

Wright Pierce

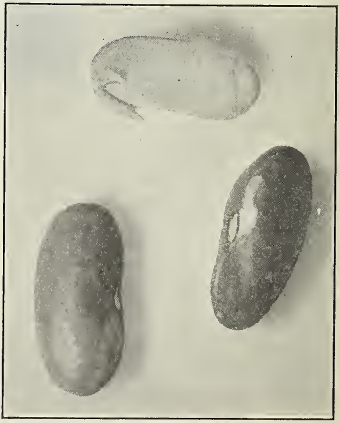
This wild azalia is being pollinated by a butterfly. Can you see how this might happen?

Some Ways in Which Cross-Pollination Is Brought About. One of the most interesting projects you can work out is to see how many different adaptations you can find in flowers which help to bring about cross-pollination. Some of the devices are so ingenious that they seem almost human. Bright colors are means of advertising to the insect that the flower contains nectar and pollen. Often a sweet odor plays an important part in attracting the bee, but some flowers which are pollinated by flies have an unpleasant odor, almost like decaying meat. Frequently flowers have remarkable devices such as are shown in the illustrations, which enable them to be sure of either self- or cross-pollination. Bees visit flowers not for the purpose of pollinating them, but to get food to take back to the hive. This food is the nectar which is usually hidden deep within the flower and the pollen which is mixed with the nectar and made into bee bread after it is taken to the hive by the bees. These insects in getting nectar become covered with pollen which they carry to other flowers. Besides insects, birds, wind, water, or man himself may be means of carrying pollen from one flower to another.



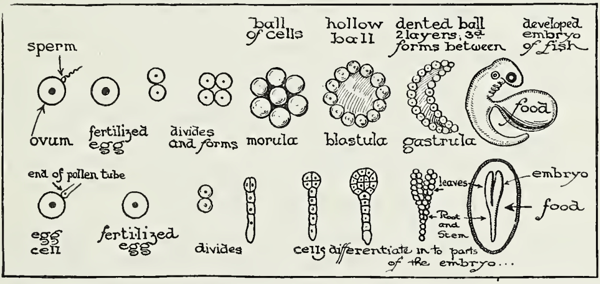
Study the diagram carefully and then trace what happens to the pollen grain when it leaves the anther.

The Development of an Embryo. As a result of pollination, the sperm cell from the pollen tube and the egg cell within the ovary come together. This union of egg and sperm cell is known as the process of *fertilization.* As a result of this union a single cell is formed, but almost immediately this cell divides into two, then these two into four, these four into eight; the cells dividing until a little baby plant or *embryo* is formed within a seed. You have all seen such an embryo when you opened a bean seed. This embryo remains dormant until a time when the seed is placed in favorable conditions for germination or growth. We know that plants in the garden require a certain amount of warmth, water, and soil. Under these conditions the baby plant within the seed is awakened to activity and starts to grow. Eventually it will produce fruits containing seeds. These seeds in turn will give rise to new plants. This round of events we call the *life cycle.*



Three views of a kidney bean. The upper one shows the young bean plant beginning to grow.

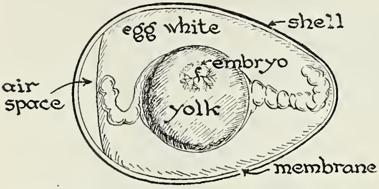
Development in Animals. Plants and animals are similar in that an embryo can develop only from an egg cell which has combined with a sperm cell in the process of fertilization. You have all probably seen a mass of freshly laid frog's eggs. These eggs, surrounded by a mass of jelly, are laid in water in the early spring by the female frog. The male frog discharges some sperm cells over the eggs, and the sperms enter the egg cells, a single sperm cell and a single egg cell uniting to form a fertilized egg. After an egg cell has been fertilized, it will develop into a little tadpole or baby frog. If you examine a mass of frog's eggs, you will doubtless find them in the process of division. Just as in the plant, so in an animal: the fertilized egg divides first into two, then into four, then into eight, then into sixteen cells. These cells keep on multiplying until within a few days, if the weather is warm, the embryo of the frog begins to elongate. In another day the little tadpole wriggles out of the jelly which surrounds the egg and begins to wriggle about until it finds a place to attach itself by means of a disk-like sucker to some water weed, stick, or stone. A little later a mouth develops and it begins swimming about after food. At this stage of its life, it eats plant food, but later it completely changes its habits and feeds on flies and other insects. These tadpoles after a time grow hind legs, and then front legs. About the same time the tails are absorbed into the body and eventually the tadpoles develop into young frogs. Finally lungs replace the gills and the frog is prepared to live on


sperm
ovum
fertilized egg
divides and forms
ball of cells
morula
hollow ball
blastula
dented ball 2 layers; 3d forms between
gastrula
developed embryo of fish
food
end of pollen tube
egg cell
fertilized egg
divides
cells differentiate into parts of the embryo...
leaves
Root and Stem
embryo
food

Sex cells of plants and animals develop into embryos. In what respects are plants and animals alike?

land. Not until the female frogs are adults do they lay eggs and thus perpetuate their own kind.

Some of you may have seen stages of development of a chick within an egg. Here the embryo is protected by the egg shell, and its development is brought about naturally by the mother hen incubating the eggs with the warmth of her own body. In mammals, the fertilized eggs are held within the body of the mother, where they grow. As soon as the embryos have developed completely, they are ready to be born.



The embryo of a chicken. Compare the development of a chicken with that of a frog.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

stigma
wind
embryo
born
sex
chromosomes
egg
cell
ways
division
protected
inheritable
incubated
ovary
fertilized
body
pollen
insects
mother
birds
different
pistil
same
tube
worms
sperm

Plants and animals possess (1)____ cells which hand down by means of the (2)____ the qualities that are (3)____. In pollination a (4)____ (5)____ containing a sperm cell falls on the (6)____ of the (7)____ of another flower of the (8)____ species. This causes the growth of a pollen (9)____. A (10)____ cell passes down this pollen (11)____ and unites with an (12)____ (13)____ found in the (14)____ of the flower. Pollination is brought about by (15)____ which carry pollen, by the (16)____ and in other (17)____. In animals and plants after the (18)____ is (19)____ by the sperm, (20)____ of the egg takes place which results in the formation of an (21)____. In birds this embryo is (22)____ in the egg and (23)____ by the mother; in mammals the developing embryo is held within the (24)____ of the (25)____ until it is (26)____.

PROBLEM TEST

A bee carries a very great number of different kinds of pollen grains when it passes from flower to flower in a garden. What are the chances of *all* of the sperm cells in these grains uniting with egg cells and why? *Match your answer with a reason or reasons given below. Some of the reasons are true and some false.*

Answers

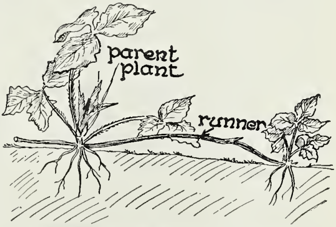
1. very great
2. very slight
3. none whatever

Reasons

1. The bee takes most of the load of pollen to the hive.
2. The bee, in passing from flower to flower, must deposit a large number of the pollen grains on the stigmas of other flowers.
3. Bees usually visit the same kinds of flowers in a garden.
4. All of the pollen falling on a stigma is sure to germinate.
5. There are probably as many egg cells as there are sperm cells.

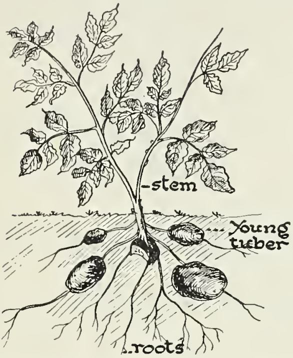
PROBLEM II. WHAT ARE SOME METHODS OF PLANT PROPAGATION?

New Plants May Form from Buds. Although we are not all farmers, almost everybody who reads these lines has noticed the way in which some kinds of weed-like grasses propagate themselves and spread through our lawns. Such plants send out stems which either run along the surface of the ground or just beneath it and send down masses of roots every short distance. If you examine such an underground stem, you will find that where the roots come out a little cluster of leaves will grow and if one of these clusters is torn away from the parent plant, it will live as a new plant. Gardeners make use of this kind of plant propagation when they grow strawberries from runners or raspberries from the bent-over stems. A very similar thing happens when a farmer plants



Producing new strawberry plants.

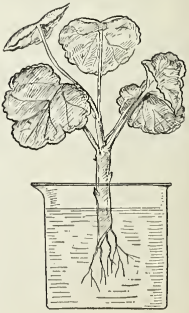
potatoes. The potato is a stem which has been modified to live underground. If you examine a potato carefully, you will notice the little indentations or "eyes" on its surface. These "eyes" are made up of a number of tiny buds some of which when planted will be likely to sprout. The potato, which is a mass of food, is used by the bud until it has a start in life. The great redwood trees in northern California propagate themselves in somewhat the same way. In a cut-over region one can see hundreds of young trees sprouting out from the base of the cut stump. If you get a redwood "burl" and place it in water, you will soon see little green knobs beginning to appear, soon followed by sprouts which grow into branches which can be kept alive for long periods of time if kept well moistened. Evidently buds give rise to branches or even in some cases to new plants.



A potato plant. Notice the stem growing from the old seed potato.

Propagation from Leaves. Very rarely leaves will give rise to new plants. Such leaves are of the fleshy variety, like the begonia. An interesting experiment would be to pin down a begonia leaf on wet sand, keeping the sand well moistened and the leaf covered with an inverted glass jar. Roots will sprout from the cut stem of the leaf and the cut ends of the veins and the young plants will grow from these points.

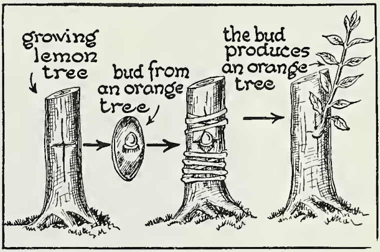
Propagation from Cuttings. Cut healthy shoots from any easily obtainable plant such as geranium, verbena, or nasturtium. Make cuttings from these shoots by cutting off pieces each of which must contain at least two nodes (areas where the leaves come out). Remove some of the leaves and cut the others to reduce evaporation. As soon as



you have made a cutting, place it in cold water. When all are made, plant in a shallow box in 4 or 5 inches of moist sand. The cuttings must be firmly set in the sand to about half their length. Keep the sand moist and record the time it takes for roots to form. Many of our common fruits, as grapes and currants, are grown from cuttings, while some trees, like the willows, cottonwoods, and poplars, propagate themselves in this way.

Demonstration 3. How to Make a Bud Graft.

The material to be used for budding should be cut while dormant and packed in a cool damp place until time of use. The best stocks for budding are young seedling trees. The stocks are prepared for the bud by making two incisions in the bark in the form of a cross as shown in the cut. The size of the bud has been much enlarged so as to show how to place it within the incision. Make incisions on north side of the tree and close to the ground.

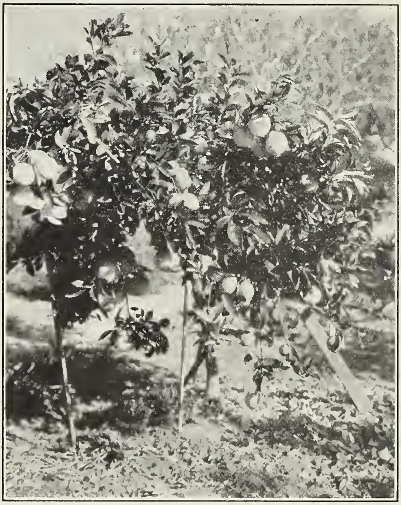

growing lemon tree
bud from an orange tree
the bud produces an orange tree

Prepare the bud by placing knife $\frac{1}{4}$ inch below bud, cut into wood and come out $\frac{1}{4}$ inch above bud. Peel bark off carefully, leaving wood behind. Next turn back edges of bark of the incision and slip bud into place. Wrap with moist raffia above and below to bring parts into close contact.

After 10 days or two weeks, when bud has united with the stock. remove raffia.

Budding. The fruit grower makes use of this ability of the bud to produce a new plant in another way. Our fruit trees such as apple, cherry, peach, plum, orange, lemon, and grape plant are rarely grown from seed. If, for example, all of the seeds from a winesap apple were planted under excellent conditions, it is unlikely that more than two or three seeds would produce winesaps. The rest of the seeds would produce fruit like their ancestors produced. So it has become the custom to either bud or graft the desired fruit to a healthy stock. This is done in the following way. A single bud is cut with a sharp knife from the tree bearing the desired fruit. This bud, with part of the bark around it, is then inserted in a T-shaped cut made in the bark of the tree which is to be budded. Then the bud is placed in the cut, bound into place with raffia or strips of cloth which has been soaked in melted grafting wax. The reason that the bud will grow is because when it is placed in the cleft, the layer which carries sap or food to it is placed against the similar layer in the bark of the tree in which the bud is placed. When these two layers come together, the bud receives food from the tree on which it is placed and so begins to grow.

Grafting. This method of propagation is very similar to budding, only here we use a small branch which is either inserted in a healthy root of a young plant or into another branch. Here again a sharp knife must be used; the layer which carries the sap in the grafted branch must meet exactly the same layer in the tree to which it is grafted. Pressure must be used to

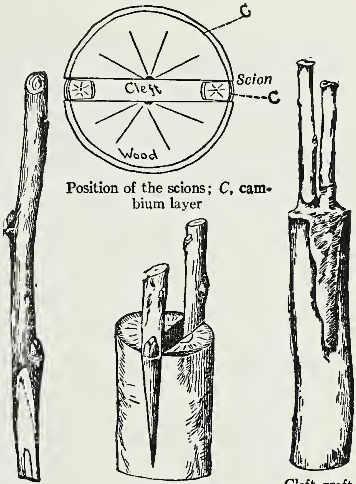


Wright Pierce

Oranges, lemons, and grapefruit may all grow on the same tree. Do you know how this is done?

push the two parts together and all cut surfaces must be covered with grafting wax so that the sap will not be lost through the cut end of the branch.

Value of These Processes. When we realize that practically all of our fruits come from grafted or budded stock, we see how important these processes are. Apples, pears, cherries, plums, and peaches are all produced in this way. Our oranges, lemons, and grapefruit are also raised from grafted or budded stock. All seedless oranges have been obtained from an original single tree which bore seedless oranges.



Position of the scions; *C*, cambium layer

Scion

Scions in the cleft

Cleft graft complete

Grafting. The scion is taken from a tree having the kind of fruit desired and placed in a tree of the same species. Why are the scions placed in the cleft in this position?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

- seeds
- propagated
- willow
- oranges
- stems
- grasses
- seedless
- point
- cottonwood
- geranium
- strawberry
- orange
- citrus
- raspberry
- grafting
- begonia
- budding
- cuttings
- bud
- nut
- branch
- root

Although plants grow from seeds, they are (1)____ in other ways. Runners and underground (2)____ strike root and a new plant arises at that (3)____. This is seen in many (4)____, the (5)____ and (6)____. A few flowers like the (7)____ form new plants from cut areas in their leaves. Many plants can be grown from (8)____ on which several buds are found. This ability of the (9)____ to grow into a new plant is made use of by fruit growers in the (10)____ and (11)____ of fruit trees.

The (12)____ industry depends on this method of propagation. All of our (13)____ oranges are said to have thus come from one (14)____ tree which gave rise to (15)____ without (16)____.

PROBLEM TEST

A citrus fruit grower has a grove of orange trees that are good sturdy seedlings but bear poor oranges. He wishes to get a good yield of grapefruit and lemons. What will he do?

From the statements given below, select what you think is the best answer to his problem, then match by number from the reasons given below the one that best fits your answer. Some of the reasons are true and some false.

Answers

1. He should plow up the field, cut down his trees, and replant with grapefruit and lemons.
2. He should cut back his trees to form stocks for the buds of excellent varieties of grapefruit and lemon.
3. He should not use his graft for grapefruit or lemons, but rather graft oranges.

Reasons

1. Buds of grapefruit or lemons will grow well on orange stock because they all belong to the same family.
2. Young seedling trees cost less than budding trees.
3. Orange buds will grow only on orange trees.
4. It is possible to have grapefruit, lemons, and oranges all on the same tree.
5. It takes much longer for young trees to come to bearing than it does good buds on a strong stock to come to bearing.

PROBLEM III. WHAT FACTORS ARE AT WORK IN PLANT AND ANIMAL BREEDING?

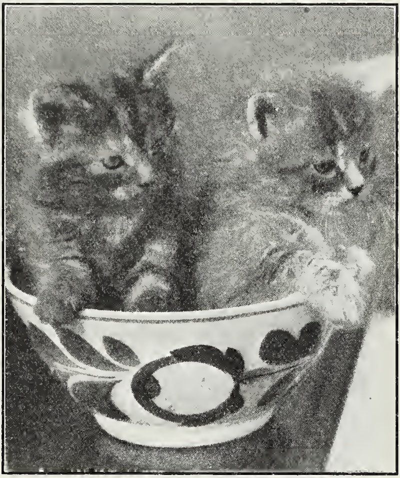
Demonstration 4. To Determine if There Is Individual Variation among Members of the Class.

Materials. String, rule, graph paper.

Method. Carefully measure with the string the circumference of the right wrist of a member of the class and let him measure yours.

Observations. Hand all the measurements, given in inches, to one member of the class who will tabulate the figures on the board. Make a graph showing the individual variations.

Heredity and Variation. You all know that different plants or animals are not alike in all particulars. Plant a dozen kernels of corn each from the same ear, and you will find that no matter how careful you are to give each seed the same amount of water and heat, yet the young corn plants will each differ slightly in size and appearance from its neighbors. Each kitten in a litter shows individual characteristics. One may be a spitfire, another most affectionate, one sleepy, or another active. Examination of any group of like animals or plants will show this tendency to vary. Such variations as these are continuous variations. On the other hand, animals and plants produce the same kind of animals and plants. The corn grains will all give rise to corn plants and no other kind. The mother cat gives birth only to kittens. But there are a good many kinds of cats and dogs that you can doubtless name. We know, however, that during the time of man's life on the earth, all of the present breeds of dogs have been developed. The original dog was undoubtedly a wolflike animal, and all of the breeds we find at the present time have come from this one form. The same is true of our cultivated grains. Originally, they came from wild grasses. The two factors of variation and heredity, that is, the tendency to be slightly different, and the fact that like produces like, have been made use of by plant and animal breeders for many generations.

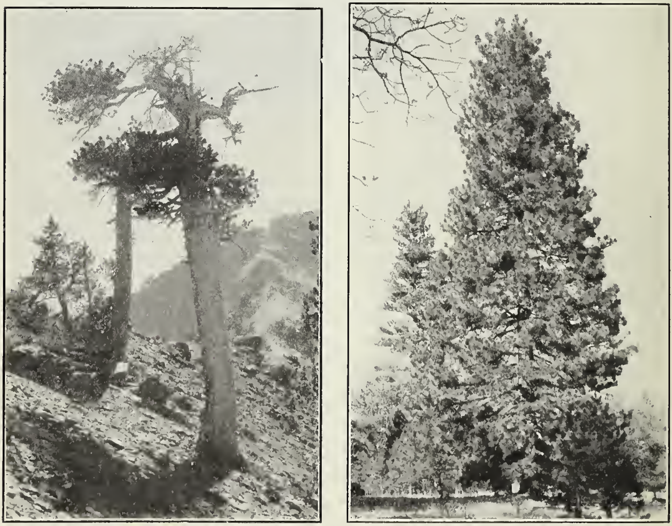


John Muir Technical High School

Are all kittens of the same family alike?

What Causes Variation. If you go up to the top of the mountain, you will find the trees growing there are stunted, wind-blown, and very different in appearance from the same kind of trees growing in the valleys. You all know the difference in appearance of plants grown in rich soil and those grown in poor soil. You have seen that water given in moderation produces beautiful plants, while too much or too little will either kill the plants or make them very different from those grown under a moderate water supply. Evidently environment has a great deal to do with certain kinds of variations. On the other hand, the seeds from that twisted, wind-blown tree, if planted in the valley, will probably produce trees like the other trees of its kind in the valley. An animal produced by a sickly parent will often be perfectly healthy if proper care is taken of it, and a child born of healthy parents will be sickly if exposed to unfavorable conditions.

There are, however, some kinds of variations that breed true and produce offspring like their parents. Such was the famous Ancon sheep, which appeared in Massachusetts in 1791. It had short, crooked legs and a long back. It was thought to be a valuable breed because it could not jump fences, but now it has passed out of existence and another kind of sheep has taken its place. In 1889 a hornless bull calf appeared in a herd of Hereford cattle.



Wright Pierce

These two pine trees are the same species, but have grown in different locations on the same mountain. How do you explain the differences?

J. C. Allen

Purebred beef cattle. What characters are evident? Beef cattle need plenty of shade and water.

A hornless Hereford has been bred from this one calf and anyone driving through the Great Plains today is struck by the number of hornless cattle to be seen there. The equally famous example of a beardless wheat came from the chance discovery of three beardless heads of wheat by a man named Fultz. The grains from these when planted later gave rise to a beardless wheat plant. It is said that Luther Burbank produced the famous Burbank potato by a chance discovery of a potato ball on a potato plant. He planted the seeds in this ball and obtained, among other potatoes, the one which now bears his name. Such types of variations are known as *discontinuous variations* or *mutations*. The name mutation was first used by Hugo de Vries, a Dutch botanist who observed this type of variation in primroses.

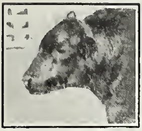
Gregor Mendel and His Law of Unit Characters. About the middle of the nineteenth century, an Austrian monk, Gregor Mendel, while experimenting with the breeding of peas in the garden of his monastery in Brunn, made a discovery which has

Bearded and beardless wheat. What would be the advantage of the beardless types?

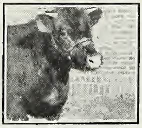
meant more than any other to those who are trying to improve plants and animals. Mendel found that the characteristics were handed down from one generation to another as definite unit characters, such as the color of the peas, the shape of the pods, and the tallness or the shortness of the plants. He made this discovery by crossing or pollinating one kind of pea with the pollen from another kind of pea.

The Law of Dominance. Mendel found also that one of these characteristics, when it appeared in the next generation, would take dominance over another characteristic. He found, for example, that when a tall pea and a dwarf pea were crossed, all the offspring were tall. In the illustration the characteristic of being hornless is dominant over being horned in cattle. The characteristic horned is said to be *recessive,* while the characteristic hornless is said to be *dominant.*

The Law of Segregation. When Mendel bred yellow-seeded and green-seeded peas, he found all the offspring had yellow peas in the pod. These peas were really *hybrids*, that is, they were the offspring of two parents which differed in respect to certain unit characteristics. If these hybrids were bred with other hybrids of the same kind, the offspring in the next generation would be



PP or hornless



pp or horned

Parents when bred together give rise to

Pp

Pp

the F_1 or first generation.
All the children of this generation show the dominant characteristic, although the animals are hybrids.

PP

Pp

Pp

pp

The second or F_2 generation shows 25% of the offspring pure *PP*, 50% hybrids or *Pp*'s, and 25% pure recessives or *pp*.

In this illustration the letter *P* is used to represent the dominant character hornless or polled and the small letter *p* the recessive character horned. A pure breed of the hornless type will then be shown as *PP*, a pure breed horned type by *pp*, and a hybrid by *Pp*.

produced in the ratio of three yellow to one green, or three dominant to one recessive. But if the hybrid peas were bred with green peas (a pure recessive), the offspring would be produced at the rate of about two dominant to two recessive. If the hybrid is crossed with a pea of the yellow variety (a dominant), then all dominants are produced in the next generation. This hereditary tendency is called the *law of segregation.*

Use of This Knowledge. Since it is quite evident that a knowledge of these laws is of very great importance to breeders, hundreds of biologists are trying to find out new dominant and recessive characteristics in plants and in animals, for it is only by a knowledge of these characteristics that intelligent breeding can take place. By means of a knowledge of Mendel's law it is quite possible for those who are trying to improve the existing plants and animals to breed for exactly those qualities that they wish. Many heritable traits in man as well as in plants and animals seem to be subject to these natural laws. Thus we see that the application of all this knowledge is of tremendous consequence to the future of the human race.

Demonstration 5. To Show How Hybridizing Is Accomplished.

Materials. Plant bearing flowers (red and white geraniums may be used); a manila bag; a camel's-hair brush.

Method. Tie a manila bag over a flower that is about ready to open. Find another flower that is about to open, on a plant of the same family though another variety or preferably another species, and from that flower remove all the stamens. Tie a bag over it also.

When the flower in the first bag opens, transfer by means of a small camel's-hair brush some of its pollen to the stigma of the flower without the stamens. Put the bag over the second flower again, placing a label on it.

Observations. Why do we take so much care in covering the flower? Why such care to transfer the pollen? Remember that as a result of this transfer, the sperm cell of one flower may unite with the egg cell of another having quite different qualities. What kind of flowers might you expect to develop from the seeds of the second plant?

Conclusion. What is the use of hybridization?

The Work of Some Practical Breeders. In this country the name of Luther Burbank stands prominently as a great creator of new forms of plant life. Burbank used selection with hybridization or crossing in order to obtain his wonderful new fruits, but he did not use the Mendelian principles referred to above. He worked with great numbers of plants, using thousands where other plant breeders used hundreds. Then he had a genius for selecting the plants of near relationship showing the characters he wished to perpetuate. After selecting his plants, he grew them under excellent conditions until they were mature and bore flowers. He then carefully covered the flower bud on one of these plants and at the proper time cut off the stamens before the pollen was produced. Then he dusted the stigma of the pistil with pollen from another plant which had the qualities he wished to cross with the first plant. If these two plants were near relatives, the pollen might grow and a new variety might be produced. He thus used the two methods of selection and hybridization.

Many practical discoveries in plant and animal breeding have been due to chance discoveries. Some of these, such as the Fultz wheat and the Burbank potato seed balls, have been mentioned. It is said that the superior Marquis wheat, which now covers over 15,000,000 acres in Canada and the northern part of the United States, owes its existence to the lucky discovery of three superior wheat plants which showed the characteristics of hardiness that the plant breeders wanted. Then came years of selection and crossing which finally gave the world the hardy variety of wheat needed for planting in the northern part of this country.

To What Extent Is Mendel's Law Used in Plant and Animal Breeding? Although breeders of plants and animals have long practiced selection as their chief tool for betterment of stock, it is in comparatively recent time that Mendel's laws have been made much use of in a practical way. Plant diseases such as rusts and blights are among the worst enemies of the farmer. It has been discovered that resistance or immunity to these diseases has been found to be dominant to susceptibility in several different kinds of plants, among them being wheat, corn, oats, rye, barley, beans, tomatoes, and peas. This immunity in wheat seems to be caused by a single pair of factors in some cases and several pairs of factors in others. Most wheats resistant to rust are hybrids. In one case an Egyptian wheat which was resistant to one kind of rust was crossed with an Australian wheat which was resistant to another kind of rust, with the result that a variety was obtained that was resistant to both rusts. In corn we find hybrids which yield much larger crops and are more hardy than the parent plants. Here again certain characters are found dominant to others which are recessive. This use of Mendel's law has been extended to tobacco, flax, grapes, and many other crops.

A crossbred Angus-shorthorn heifer. What character is dominant here?

Some very interesting experiments with chickens resulted in finding out that egg production as well as size and color of shell are due to certain Mendelian characters. Richness of milk in cattle appears to be due to Mendelian characters, as well as quality, length, and fineness of wool in sheep. Many other examples might be given to show that breeding of plants and animals is proceeding in a much less haphazard way than was practiced before the discovery of Mendel's laws.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

related
improve
producing
variation
breeds
haphazard

time
place
came
unit
hybridization
heredity

laws
certain
good
bad
continuous
Mendel

desired
discontinuous
hereditary
Darwin
de Vries
unlike

Two factors are used by plant and animal breeders; they are (1)____ and (2)____. Variations are of two kinds, (3)____ and (4)____; the latter produce plants and animals quite (5)____ those from which they (6)____. Such variations breed true and are of value in (7)____ new plants and animals. An example is seen in the various (8)____ of cattle. Heredity works through definite (9)____. Those discovered and formulated by (10)____ are used most generally by plant and animal breeders. (11)____ qualities are handed down in the form of (12)____ characters. At the present time, plant and animal breeders, instead of attempting to (13)____ their stock in a (14)____ way, try to produce better breeds which have (15)____ (16)____ characteristics. This is usually done through (17)____ or cross-breeding two nearly (18)____ forms.

PROBLEM TEST

John was much interested in plant breeding and tried the following experiment: He proceeded to pollinate a flower on his favorite apple tree with the pollen from a red hollyhock that was in bloom. He took all the precautions mentioned on page 478.

Will his experiment succeed, and if not, why not? Match your answer with the reasons given below.

Answers

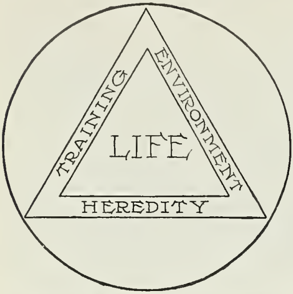
1. His experiment will succeed and he will get a tree bearing red apple blossoms.
2. He will get fruit formed as a result of the experiment, but being a hybrid, it will have no seeds.
3. His experiment will not succeed.

Reasons

1. In crossing experiments great care must be taken. John performed his experiment carefully.
2. In making a successful cross the two plants must be of the same species or at least closely related.
3. Fruit formed from hybrids does not contain seeds.
4. Red color in hollyhocks is dominant over white color in hollyhocks.

PROBLEM IV. HOW MAY THE HUMAN STOCK BE IMPROVED?

The Triangle of Life. How many of you have heard the question, "Which is the more important for a person, his heredity or his environment?" It is something that a good many people debate every day and on which they come to no definite conclusion. As a matter of fact the life of each one of us is influenced by three factors: *heredity,* or what we are; *environment,* or what we have and *training,* or what we do. Let everyone now ask himself the question, "What part does heredity play in my life?" Knowledge that the race is gradually changing, that there is a constant improvement or evolution, makes us ask, "Can these laws of heredity of which we have just learned be applied to the human race?" We know if we look into our histories that men and their environments have been changing since long before the birth of Christ.



The triangle of life. How might this triangle be changed in appearance?

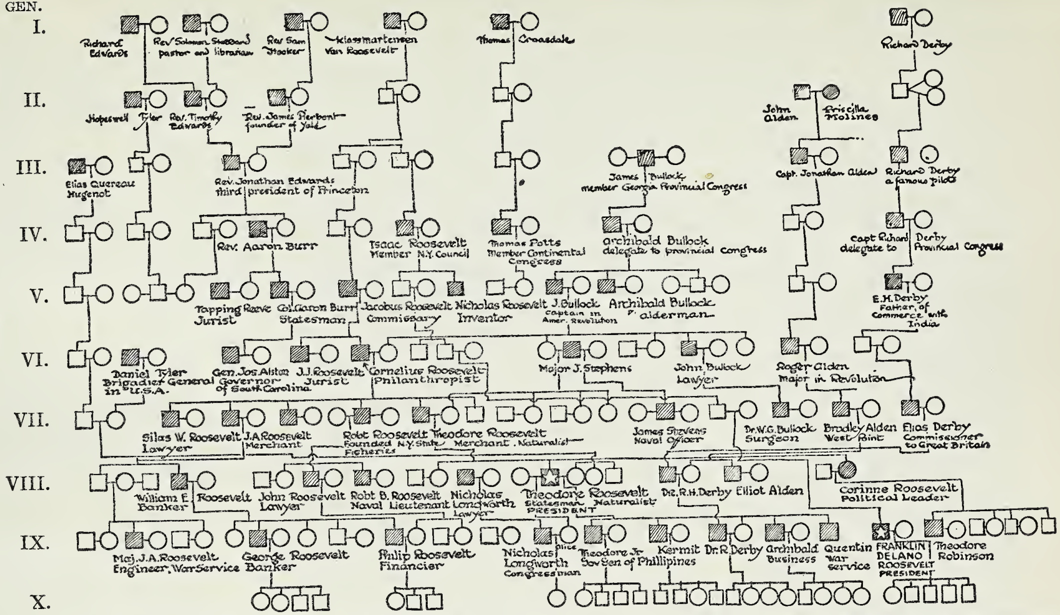
It is quite evident from what we have read on some of the previous pages that through personal hygiene and improvement of the environment, a healthier and stronger race has been produced. But if we study the records of some of the royal families of Europe, of certain well-known families in this country, and of other not so well-known families which have become a burden on society, we find that *breeding* in man as well as in plants and lower animals must be taken into account.

Does Inheritance According to Mendel's Law Take Place in Man? As soon as Mendel's law was rediscovered, scientists at once began to see if it applied to inheritance in man. A number of examples were soon found which definitely showed the working of the law. An interesting case of stiff-jointedness is recorded in a family that dates back for over 500 years. In this trouble the ring and middle fingers have no joint between the end bone and the one next to it. An Englishman who had this abnormality and whose father and mother both had the same difficulty traced his ancestry back to Henry Talbot, first Earl of Shrewsbury, who was killed in battle in 1453 by a blow in the head from a battle-ax. He also had a broken thighbone. In 1874 his tomb was opened and his skeleton was identified by these wounds, but his skeleton was also found to have the same abnormality of finger joints found in his present-day descendants. This defect was inherited through 14 generations as a Mendelian dominant. Other physical traits are the forelock of white hair which acts as a dominant character in many families; brown eyes, which are dominant over blue eyes; curly hair over straight hair; and many others. Some physical and mental traits seem to be caused by several Mendelian characters acting together so that it is more difficult to say exactly what will happen in mating. But we do know that high intellectual attainment runs in families just as crime and degradation runs in others. And we also know that it is not the environment that always causes the crime, any more than it is the environment which always conditions an individual's life. There are too many examples of men like Lincoln, Steinmetz, Pupin, or Booker T. Washington, who have made good in spite of the handicaps of their environment. Let us look into some of these examples a little more closely.

Case of the "Jukes." A number of years ago there lived in an isolated part of New York state a family of ne'er-do-wells. This family, known as the Jukes, has been carefully studied. Up to 1915, 2094 members of this family had been traced. Of this number 1600 were feeble-minded or epileptic. There have been 310 paupers; and 140 criminals, of whom seven were murderers. Not a soldier had appeared in the family and not one had a common school education. Only twenty had learned a trade and ten of these learned it while in prison. The family had cost society over $2,500,000 up to that time. And why? Because the original stock was feeble-minded, and through marriages with others of the same mental ability, feeble-mindedness was handed down to the other generations. Feeble-mindedness is thus seen to be a hereditary characteristic.

Parasitism and Its Cost to Society. If this family were the only feeble-minded one, it would be bad enough, but there are probably from 300,000 to 500,000 feeble-minded persons in the United States today, and records have been made of a number of families which show the inheritance of feeble-mindedness. Feeble-mindedness seems to be a recessive Mendelian characteristic probably caused by several factors rather than one. Such persons spread disease, crime, and immorality in all parts of the country, chiefly because they know no better. Just as certain plants or animals become parasitic on others, so these people have become parasites on society. They take from society, but they give nothing in return. In the valley of Aosta in Italy a few years ago there existed a number of idiots known as cretins. Probably over 50 per cent of the inhabitants of this little mountain valley were so affected. But due to wise planning these defective people were segregated, the males in one asylum and the females in another. Since that time the race of cretins has gradually died out and one scarcely ever sees any of these defective people in that country now. This is one of the most effective means by which feeble-mindedness can be eventually blotted out from the earth. This can only be done by segregation of such people into institutions and some means taken to prevent their reproduction. Several states and at least one country, Germany, have laws which allow such persons to be sterilized or rendered incapable of reproduction.

The Part Played by Alcohol. Whether alcohol causes feeble-mindedness is a question, but we know that alcoholism and feeble-mindedness are associated, as is shown by a study of statistics. We also know that there are more nervous diseases such as epilepsy, and more tuberculosis in families of drunkards than in those who do not drink, but here again it may be that other conditions play a large part. But we do know of experiments which seem to show that the stock is injured by alcohol and that these injuries are handed down to the children of such alcoholics. Dr. Hodge made experiments with dogs and Dr. Stockert of Cornell Medical School made similar experiments with guinea pigs in which they found that the effects of alcohol given to the parents were shown by the offspring. Dr. Hodge had four dogs, two of which were given alcohol with their food every day, although not enough to have them show intoxication. The two alcohol-fed dogs had 4 out of 23 puppies able to live, with 15 born dead, while the two dogs which had no alcohol had 41 out of 45 puppies able to live, with none born dead. In the case of the guinea pigs, the alcohol was given by inhalation, as the guinea pigs did not like it in their food. These experiments indicate that alcohol may play a decided part in making the human race more sickly and less able to withstand disease as well as be a possible cause of mental diseases.


GEN.
I.
II.
III.
IV.
V.
VI.
VII.
VIII.
IX.
X.
Richard Edwards
Rev. Solomon Stoddard pastor and librarian
Rev. Sam Hooker
Klassmartensen Van Roosevelt
Thomas Croasdale
Richard Derby
Hopewell Tyler
Rev. Timothy Edwards
Rev. James Pierpont founder of Yale
John Alden
Priscilla Molines
Elias Quereau Hugenot
Rev. Jonathan Edwards third president of Princeton
James Bullock member Georgia Provincial Congress
Capt. Jonathan Alden
Richard Derby a famous pilot
Rev. Aaron Burr
Isaac Roosevelt Member N.Y. Council
Thomas Potts Member Continental Congress
Archibald Bullock delegate to provincial congress
Capt Richard Derby delegate to Provincial Congress
Tapping Reeve Jurist
Col. Aaron Burr Statesman
Jacobus Roosevelt Commissary
Nicholas Roosevelt Inventor
J. Bullock Captain in Amer. Revolution
Archibald Bullock alderman
E.H. Derby Father of Commerce with India
Daniel Tyler Brigadier General in U.S.A.
Gen. Jos Alston Governor of South Carolina
J.J. Roosevelt Jurist
Cornelius Roosevelt Philanthropist
Major J. Stephens
John Bullock Lawyer
Roger Alden Major in Revolution
Silas W. Roosevelt Lawyer
J.A. Roosevelt Merchant
Robt Roosevelt Founded N.Y. State Fisheries
Theodore Roosevelt Merchant. Naturalist
James Stevens Naval Officer
Dr. W.G. Bullock Surgeon
Bradley Alden West Point
Elias Derby Commissioner to Great Britain
William E. Roosevelt Banker
John Roosevelt Lawyer
Robt B. Roosevelt Naval Lieutenant
Nicholas Longworth Lawyer
Theodore Roosevelt Statesman Naturalist PRESIDENT
Dr. R.H. Derby
Elliot Alden
Corinne Roosevelt Political Leader
Maj. J.A. Roosevelt Engineer, War Service
George Roosevelt Banker
Philip Roosevelt Financier
Nicholas Longworth Congressman
Alice
Theodore Jr. Sov. Gen. of Phillipines
Kermit
Dr. R. Derby
Archibald Business
Quentin War Service
FRANKLIN DELANO ROOSEVELT PRESIDENT
Theodore Robinson

Study this chart carefully. What evidence have we that heredity plays a part in shaping the careers of individuals in certain families? (Redrawn from chart by Dr. H. H. Laughlin, Department of Genetics, Carnegie Institution of Washington)

The Inheritance of Moral and Mental Characteristics. Fortunately, the bad side of heredity is not the only one. A study of certain distinguished families has shown that genius and valuable mental traits are also handed down. An interesting example is seen in the Darwin-Wedgewood family in England. In five generations of this family, 17 out of 24 men have been noted in science or in letters. In this country, the Jonathan Edwards and the Roosevelt families have been notable examples.

The Meaning of Eugenics. The above paragraphs show us that blood will tell, or rather, to put it more scientifically, "that the chromosomes will tell the story." It is evident that if the race is to be improved, we must improve the stock. This can be done in the same way that we improve animals or plants; that is, we must check the reproduction of the poorer strains and encourage that of individuals who are strong and healthy in every way. The science of improving the human race by better heredity is known as *eugenics.* If our country is to keep its place as a leader in world progress, we must prevent its overpopulation by defective or weak mental stock. We must, on the other hand, do all we can to have persons of the better stock mate and have children. It is said that the average college graduate's family is now less than one child, while the family of the mental defective may reach a dozen or more. If this country is to succeed, we must have brains and ability handed down to the next generation. If we could educate people to think of the future before they married, we could have fewer divorces and a healthier race in the future.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

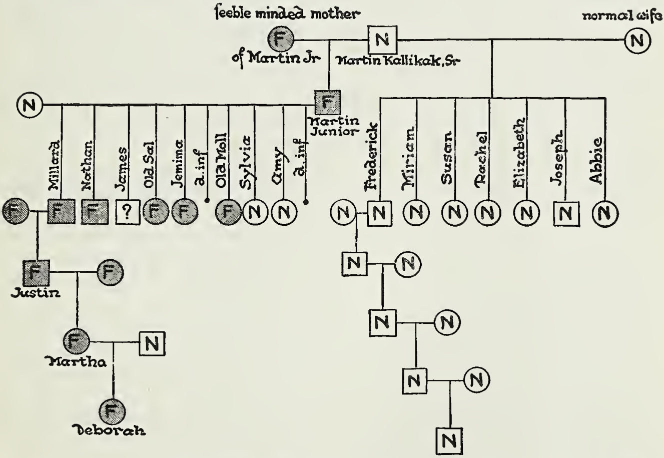
co-operation
breeding
heredity
education
prevent
Mendel's
recessive
improve
dominant
environment
mental
children
physical
training
eugenics
spoil
sanitary
better
housing
food
health
looks
disease
alcoholism

Our life is influenced by three factors: (1)____, (2)____, and (3)____. The (4)____ of future generations can be improved if people avoid marrying into families that have definite bad traits, as (5)____, and choose as mates only those who have good (6)____ and (7)____ characteristics. We have evidence that many (8)____ and (9)____ characteristics are handed down according to (10)____ laws. For example, feeble-mindedness acts as a (11)____ characteristic, while brown eyes are (12)____ over blue eyes. Feeble-mindedness and (13)____ seem to be closely associated. Eugenics is the science which aims to (14)____ the human race through (15)____ (16)____. Laws should (17)____ the (18)____ of the unfit, who would soon disappear from the earth.

PROBLEM TEST

Study the diagram carefully. F = feeble-minded, N = normal. Select from the following statements those which you know are true and match these statements with the reasons given below which show them to be true.

1. Martin Kallikak, Sr., was normal in all respects.
2. Martin Kallikak, Sr., was not normal in all respects.
3. If one parent of a mating is feeble-minded, not all of the offspring will be feeble-minded.


feeble minded mother of Martin Jr
Martin Kallikak, Sr
normal wife
Martin Junior
Millard
Nathan
James
Old Sal
Jemima
a. inf
Old Moll
Sylvia
Amy
a. inf
Frederick
Miriam
Susan
Rachel
Elizabeth
Joseph
Abbie
Justin
Martha
Deborah
F
N
?

Intelligence and lack of intelligence seem to be inherited characters. One of the lines of descent of Martin Kallikak shows feeble-mindedness inherited from a feeble-minded mother. Of 480 descendants studied, only 46 were known to be normal. The other line of 496 descendants from Martin Kallikak and a normal wife was practically all normal.

4. If both parents of a mating are feeble-minded, all children resulting will be feeble-minded.
5. If the mother is feeble-minded but the father normal, all the children will be feeble-minded.

Reasons

1. Of the 480 descendants of Martin Kallikak, Sr., by a feeble-minded girl, 143 were feeble-minded.
2. The mating of a feeble-minded person with another feeble-minded person results in all the offspring being feeble-minded.
3. All the offspring of Martin Kallikak, Sr., by a normal wife were normal and none of the 496 descendants were feeble-minded.

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. These big ideas we call generalizations. For this unit some of the more important ones are as follows:

1. Plants and animals have sex cells. The egg cell is the female sex cell; the sperm, the male sex cell.
2. The union of these two cells is called fertilization.
3. A fertilized egg under favorable conditions will form an embryo which will develop into an adult.
4. Plants can be propagated by slipping, budding, grafting, and sexually.
5. Two factors at work in plant and animal breeding are variation and heredity.
6. Chromosomes of the sex cells are believed to hand down the heredity qualities.
7. There are two kinds of variations: continuous and discontinuous. The latter is inheritable.
8. Mendel's law shows that some inherited characters are dominant over others which are called recessive.
9. The human stock may be improved by the same methods used by plant and animal breeders.
10. There are many Mendelian characters in man.
11. Eugenics means the improvement of the human race by better heredity.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT, *write numbers of all statements you believe are true. In another column under* INCORRECT, *write numbers of untrue statements. Your grade = right anwers × 2.*

I. **Seeds are formed in the ovary of a flower when:** (1) insects take nectar from the flower; (2) pollen is carried by the bee to its hive; (3) pollen deposited on the stigma grows in a pollen tube which reaches the ovary; (4) there is fertilization of an egg by a sperm cell; (5) the wind blows pollen from a pumpkin flower to a pea flower.

II. **Adaptations for cross-pollination:** (6) assist in the fertilization of the egg; (7) are fragrant odors and bright colors in the flower to attract insects; (8) are hairs on the legs of bees and other insects; (9) consist in the insect and the flower touching each other; (10) are those structures or acts which fit the insect to deposit pollen on the stigma of the flower.

III. **Development in plants and animals is similar in that they both:** (11) pass through similar stages; (12) provide food for the growing embryo; (13) came from fertilized egg cells; (14) come from seeds; (15) provide stored food for the earliest stage of life.

IV. **Variation in plants and in animals is proved by the fact that:** (16) your right hand differs from your left hand; (17) all maple leaves are unlike all oak leaves; (18) maple leaves when measured accurately are found to differ; (19) no two kittens from the same litter are exactly alike; (20) a "scottie" differs from an airedale.

V. **Heredity is important because:** (21) it means that a son will carry on the father's business; (22) a heifer from a good butter cow will probably be a good butter producer also; (23) the son of a good tennis player may also be a good tennis player; (24) the children of mentally strong parents are usually mentally strong; (25) a tree grown from a seed taken from a Baldwin apple will produce hybrid Baldwin apples.

VI. **Mendel's law shows that:** (26) characters are handed down as units; (27) the curly hair of guinea pigs will be inherited; (28) certain characteristics are dominant in inheritance over others which are called recessive; (29) if we segregate certain characters, in plants or animals, we can breed them in the next generation;

(30) breeding two recessives will produce a pure type which will breed true.

VII. **Plants may be propagated by:** (31) breeding; (32) slips; (33) hybridizing; (34) selection and then breeding; (35) grafting.

VIII. **Success in life depends upon:** (36) heredity alone; (37) training alone; (38) environment alone; (39) all of the above; (40) none of the above.

IX. **Man can improve his own racial stock by:** (41) applying a knowledge of Mendel's law to himself; (42) smoking or drinking; (43) not intermarrying with diseased stocks; (44) improving his environment; (45) eating just the foods he likes best.

X. **Eugenics:** (46) means that improvement of the environment will improve the race; (47) is the scientific improvement of the human race by the use of better heredity; (48) believes that the chromosomes are of more consequence than the environment; (49) if used properly should eventually result in a better race; (50) would not believe in intermarriage with alcoholics.

PRACTICAL PROBLEMS

1. Why do some progressive farmers keep bees?
2. How did the embryo found in the bean seed get there? Explain.
3. Make a table showing similar stages in the development of an embryo plant or an embryo animal.
4. What kinds of wheat are grown in your locality? What kind of cattle are raised? Why are these particular plants and animals raised here? Do you think the farmers are really raising what is best adapted for this particular part of the country? Why?
5. If you were appointed as a judge of a local dog show or a local flower show, on what characteristics would you judge?
6. Find out from your parents some definite peculiarities of structure or manner of your grandparents. Do you find any of these traits in yourself? Did they appear in your father or mother? Are they handed down by Mendelian law?

SUGGESTED PROJECTS, REPORTS, AND LIBRARY READING

1. Look up an article on plant or animal breeding.
2. Make a list of the plant and animal characters that have been improved through a knowledge of Mendel's law. Read all the sources of information that you can on this problem.
3. Draw plans to show how you could improve your yard. If possible, put them into effect.
4. Report on the life and work of Mendel, Darwin, or Burbank.
5. Read for pleasure some of John Burroughs' books, or Gibson's *Sharp Eyes*.

LEISURE TIME ACTIVITIES

1. Study several flowers in the field to determine just how each flower is fitted for a particular insect visitor. Watch the insect at work and report back to the class just how pollination is brought about. If charts or flower models are available, study them, and work out at least three different ways in which cross-pollination may be brought about.
2. Make a list of several related plants and related animals that you know came from wild ancestors. Name the probable ancestor in each case.
3. To what extent are these processes of plant propagation used in your region? Give examples, if possible, from observations which you have made.
4. Make a collection of pictures illustrating the development of some fruit by selection and hybridization.
5. Practice grafting according to the directions given in your text. Grafting wax may be made as follows: Melt one part tallow, two parts beeswax, four parts rosin, all measured by weight. Pour into water, grease your hands with lard and then work the grafting wax as you would pull molasses taffy. Make wax into rolls and cover with paraffin paper. Soften for use by placing in hot water.

SCIENCE CLUB ACTIVITIES

1. Have a club meeting devoted to the following questions for debate:

Resolved: That heredity is of more importance in man's life than environment.

Resolved: That training along health lines is of more value than a good business training.

REFERENCE READING

Conklin, E. G., *Heredity and Environment in the Development of Men.* Princeton University Press, 1923. For teachers.

Downing, E. R., *The Third and Fourth Generation.* University of Chicago Press, 1918. Brief. Excellent for teacher.

Guyer, M. F., *Being Well Born.* Bobbs-Merrill, 1927.

Harwood, W. S., *New Creations in Plant Life.* The Macmillan Co., 1907.

Jordan, D. S., *The Heredity of Richard Roe.* For teachers. Beacon Press, 1911.

Wiggam, A. E., *Fruit of the Family Tree.* Bobbs-Merrill, 1924.

Survey Questions

Do you believe that all the food in the world originally came from green plants?
Prove that all energy used in food making comes from the sun.
What are the main differences between energy foods and growth foods?
What crops are most valuable in this country?
Where do we get most of our energy foods?
Where do our vitamins come from?
What industries depend upon agriculture?
How is artificial ice made?
What agencies do we have to help the farmer?

UNIT XV

OUR NATION'S FOOD SUPPLY

PREVIEW

In a recent fascinating book[1] that you all should read, Professor D. T. MacDougal tells the story of how the food of the world is made by green plants. He likens the leaf or each cell of it to a factory in which this wonderful green substance called chlorophyll with the energy received from the sun manufactures sugar and other food substances. He invites us to visit with him this leaf factory and to that end we must reduce our size, like Alice in the Looking Glass land, so that we can climb down through one of the openings in the surface of the leaf into that moist chamber below. Here the visitor would have to wear a waterproof outfit and must take care that he does not slip on the moist surfaces of the cells of which the leaf is made. He would find that he could wander around in the cave-like spaces in the interior of the leaf and would find his way fairly well lighted from the sun's rays that penetrated the translucent walls of the green cells all about him. The air would be warmer than outside and very moist but would be quickly influenced by the passing of a cloud over the sun, so that there might be a drop of five degrees in a few seconds. But the visitor will be most interested in the working of the factory which he is visiting. He finds that each cell, with its jelly-like interior holding the green chloroplasts, is in reality a mill in which water and carbon dioxide and certain salts are made into new substances which are at first sugar and ultimately starches and other foods. He would find that these green mills are continually increasing their speed and slowing up, depending on the amount of light they get, the temperature of the leaf, the amount of carbon dioxide gas present, and other factors. These mills, like other factories, must have a way to dispose of their products and store them. They will not do good work if they become clogged with an accumulation of manufactured products, so they pass on their products for storage in other parts of the plant. And like man-made factories, these mills do not run at night, although they can be made to go under some forms of artificial light just as when our factories work overtime. All this and more is told by Professor MacDougal. After reading this little book, we all have a clearer idea of the great importance of green plants to mankind.

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[1] D. T. MacDougal, *The Green Leaf*, Appleton, 1930.

We have said in various places in this series of books that green plants make the food of the nations. This cannot be better illustrated than by referring to the drought in the Midwest in 1934.

Wide World

Drought conditions during the summer of 1934. Note the condition of the cornfield in the foreground.

For day after day the fields burned up, without the water necessary to run the plant factories. What was the result? The food supply of thousands of people was gone, hundreds of thousands of cattle dead or dying, the incredible sum of $5,000,000,000 lost, and all because the food factories in the green plants in the Middle West could not do their work.

Not only does our food supply depend on the green leaf factories, but notice how it affects other activities of life as well. Without crops and cattle the railroads have less freight to move, the factories which make the grain into flour are affected, the stock yards and packing plants, the canning industry, and indirectly the manufacture of cans, of farm implements, of automobiles, of radios, and of all kinds of man-made products are also affected. For without food to eat and to sell, the nation has lost its ability to purchase other materials, and with no purchasers, factories cannot produce goods. It is an endless chain that comes back again to the food factories in the green leaf.

The pages that follow will tell you something about how food is manufactured by green plants and will go on to show the sources of our nation's wealth of plant and animal food. We shall learn, too, something about some of the vocations which have come from the production and marketing of those resources.

In making a study of this unit, you will want to recall some of the facts and generalizations which serve as a foundation for the things you will learn in the pages that follow.

1. Green plants make the food of the world.
2. Foods come from both plants, animals, and inorganic matter.
3. Foods are classified as fuel foods, protective foods, and growth foods.
4. Organic foods are considered as starches, sugars, fats, oils, and proteins.
5. Most plant foods contain vitamins.
6. We need a variety of foods in order to keep well.

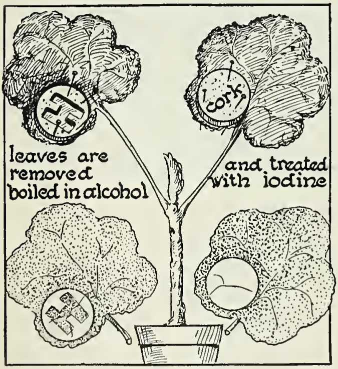
PROBLEM I. HOW DO GREEN PLANTS MAKE FOOD?

The Leaves of Green Plants Contain Starch. We have said a good deal about green plants making the food of the world. Let us see now if we can prove by experiment that a green plant makes food. We want to know first of all whether a green leaf contains food. This we have shown in another unit. We tested green leaves for starch by first removing the green color from some leaves by boiling them and placing them while still hot in wood alcohol. After the leaves have been heated for a few moments, they will be found to be free from color. If now they are placed in iodine solution for a short time, the leaf becomes blue or black. A little starch tested with iodine gives this same blue-black color. We therefore conclude that the leaves contain starch because they act as the starch does in the presence of iodine. Other green leaves tested in the same manner give similar results. We therefore say the green leaves do contain starch. Starch is one of the foods, so we can start with the assumption that green plants contain food.

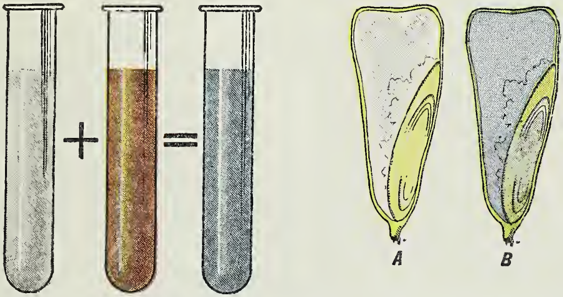
What Does Sunlight Have to Do with Starch Making? Our next step is to find out if light has anything to do with the presence of starch in the leaf. Evidently we must control this factor of light. To do this we will make the following experiment. In any scientific experiment we always use a control. That is, we make a similar experiment to the one we are trying, except that we make one factor different. This we call the experimental factor. We will make a controlled experiment in which the experimental factor will be the presence or absence of light.

Demonstration 1. Does Sunlight Cause Starch to Be Formed in a Green Leaf?

Take two healthy geranium plants as nearly alike as possible. Place both in the school darkroom for at least 24 hours. This is so that if there is any starch in the leaves, it will be used up by the plant or transported away from the leaves. Take one of the two plants and expose it to bright sunlight for from 3 to 6 hours. During this period of time, keep the other plant in a box with blackened sides and cover. After the time of exposure to sunlight is over, pick an equal number of leaves from each plant, taking them from similar positions on each plant. Boil all the leaves for a few moments and then place in methyl alcohol until the leaf green is exhausted. Then test both lots for the presence of starch with iodine. Are there any differences in the appearance of the two lots of leaves?


cork
leaves are removed boiled in alcohol
and treated with iodine

Several variations of this experiment can be made to show the effect of sunlight on starch making. An interesting one is shown in the illustration. Here two leaves in the same plant were treated differently. In one case a tiny piece of cork with the letter *H* cut in it was fastened on to the upper surface of a leaf and a similar piece fastened just under it on the opposite side of the leaf. On the other leaf two disks of cork were fastened on the same way. The plant, which had previously been placed in a dark room for several hours, was placed in bright sunlight for six hours and then the two leaves were removed with one of the untreated leaves as a control. The leaves were all boiled in methyl alcohol and then all were treated with iodine solution. The results are seen on the opposite page.



Test for starch. A few drops of iodine are added to the starch solution with the result shown in the third test tube. Explain *A* and *B*.

What Does the Green Coloring Matter Have to Do with Starch Making? We can answer this question with another experiment. For this purpose let us take a variegated coleus plant, one which has yellow, red, and green in the leaf.

Demonstration 2. Is Green Color Necessary for Starch Making?

Place the coleus plant in total darkness for at least 24 hours, then expose the plant to bright sunlight for several hours. Pick off two or three leaves while they are still in the light and test as in the previous experiments. What part of the coleus leaf, if any, contains starch?

Other Factors Necessary for Food Making. We have thus proved experimentally that both sunlight and leaf green or chlorophyll are necessary to make starch in a leaf. Food could be made wherever chlorophyll is present so that food may be made in green stems as well as green leaves. But by far the greatest amount of food is manufactured in the cells of green leaves. We could prove in a similar manner that carbon dioxide must be

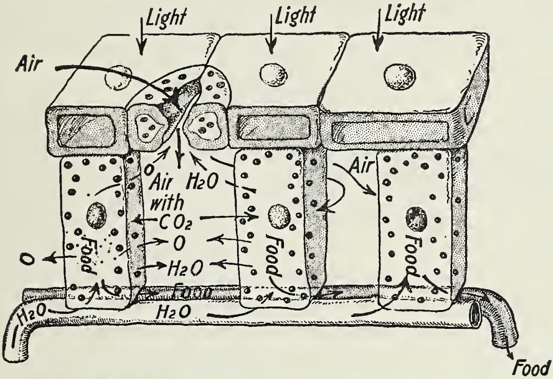
Wright Pierce

This hedge of California privet was planted and the plants were given exactly the same conditions of soil, water, and sunlight. Some of the plants as they grew showed a large number of variegated leaves. How do you account for the differences in the size of the plants shown here?

present in minute quantities in the atmosphere. We would also find that both water and several salts found in soil are necessary if starch is to be made. And still another factor that keeps the starch mills at work is a favorable temperature. So the process of food making, which seems so easy and so evident, is really a very complicated and delicate proceeding in which the green cells of the leaf must have conditions just right or the work will not go on.

Conditions Necessary for Food Making. To make food, the leaf must have the bodies called chloroplasts, sunlight, water, carbon dioxide, mineral salts, and a favorable temperature. It is evident, then, that leaves which have more chlorophyll in them will make food faster than leaves that are not so green, and leaves that are placed in a favorable position to get sunlight will make more food than leaves in shaded areas. We must remember, too, that the process of food making does not go on at night.

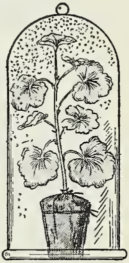
A By-Product of Food Making. As the work is done in the cells of the leaf, a by-product is given off. While the leaf is at work making sugar and the raw materials are being built up into the sugar and starch, a gas is given off as a waste product. This is oxygen. This shows us another reason why green plants are useful to man. Evidently parks with groves of trees and shrubs are really breathing places for city people.



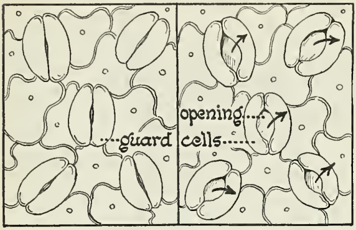
Compare the work of this part of a leaf (in starch making) with that of a mill.

Demonstration 3. Transpiration.

Take a healthy green plant such as a geranium or hydrangea which is planted in a pot, water it well, and cover the pot with a single sheet of rubber tissue. Tie the sheet tightly around the stem of the plant. Now place the plant in the sunlight and put over it a glass jar. In a short time moisture will be seen on the inside of the jar. Where did this moisture come from?



Water Is Also Given Off. Another substance which the leaf loses is water, which passes off through the little holes in the surface of the leaf. It is estimated that the leaf absorbs about 70 per cent of the sunlight it receives but it uses less than 4 per cent of this energy in making food. Consequently a large amount of heat gets into the leaf, which would raise the temperature too high if it were not gotten rid of. This removal of heat is accomplished as in our perspiration, by the evaporation of water from the inside of the leaf. These holes, or stomata, are very numerous, as many as 250,000 on a single square inch of surface. This would make a ventilating area equal to almost $\frac{1}{6}$ of the lower surface of a leaf. When we realize that plants take in a very large amount of water each day, as much as 100 gallons for a moderately large tree, then we can see that a considerable amount of water must be passed out through these openings on a warm day. A large corn plant has been found to give off over a gallon of water in a day, and a medium-sized birch tree would lose two large barrels of water in the same period of time.



When would the stomata of a leaf be open? When closed?

Summary. From what has been said, the values of green plants to man are threefold: They manufacture our food, they purify the air by releasing oxygen, and they give off moisture to the air, thus cooling the atmosphere and making it more healthful. Man certainly owes much to the green plants.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

temperature
oxygen
dioxide
green
yellow
foods
white
leaves
outside
minerals
chlorophyll
sun
carbon
sunlight
heat
starch
inside
by-product
black
trioxide
waste
blue

Green leaves may be shown to contain (1)____, for after the (2)____ color is removed they turn (3)____ when tested with iodine. This is a test for (4)____. We can prove by experiment that (5)____ is necessary for food making in leaves and that (6)____ is also necessary. It is not so easy to prove the other factors necessary, the presence of a favorable (7)____, of (8)____ (9)____ in the air and of water containing (10)____. Sugar is first made in leaves, later this becomes (11)____. Other (12)____ are also manufactured. An important (13)____ given off is the gas, (14)____. Water is also passed off from the (15)____. This keeps down the (16)____ of the (17)____ of the leaf, which absorbs much heat from the (18)____.

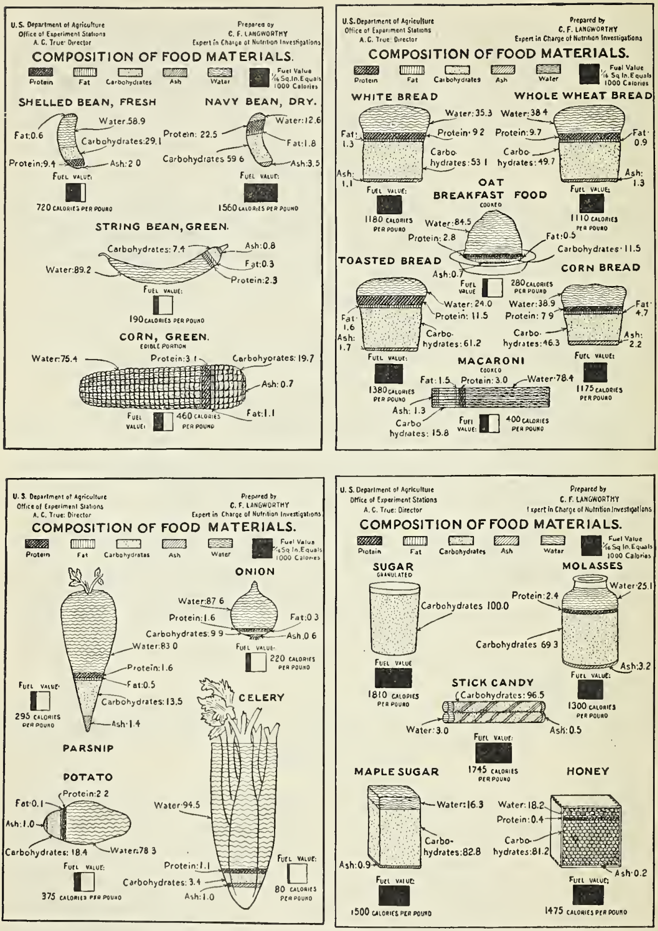
PROBLEM TEST

You have heard the statement many times that the food of the world is made by green plants. *Can you prove it by using the facts given below? Give by number those facts which you think prove your point.*

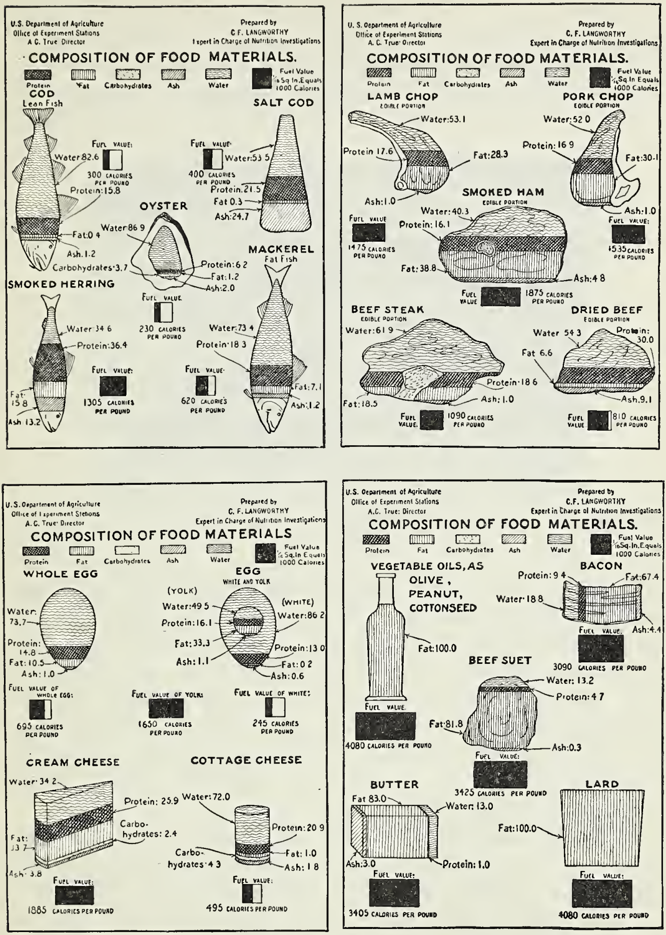
1. Certain light rays energize chlorophyll.
2. Animals eat green plants.
3. Animals eat other animals.
4. Bacteria destroy plants and animals.
5. Food consists of proteins, starches, sugars, fats, and oils.
6. Leaves contain chlorophyll or leaf green.
7. Man feeds on both animals and plants.
8. Sunlight is radiant energy.
9. The air contains a small amount of carbon dioxide.
10. Chlorophyll needs light energy to make sugar.
11. Soil contains mineral salts.
12. Air gets to the inside of the leaf through tiny holes in it.
13. Water gets into the leaf from the roots.
14. Sugar is first manufactured in the leaf, later other foods.
15. Foods from the leaves are transported and stored in other parts of the plant.
16. One condition necessary in making food in green leaves is a favorable temperature.

PROBLEM II. WHAT ARE THE SOURCES AND USES OF PLANT FOODS?

Plants Give Us Largely Energy Foods. If we think back to what we know about foods, we will remember that there are other kinds of organic foodstuffs, carbohydrates, fats and oils, and proteins. We think of carbohydrates as starches and sugars. This makes us recall the experiments we have just seen and we remember that green leaves manufacture these very substances. If you look at the charts on pages 502 and 503 you will find that foods which come from green plants are largely made up of carbohydrates. As a matter of fact, plants are energy-giving foods.



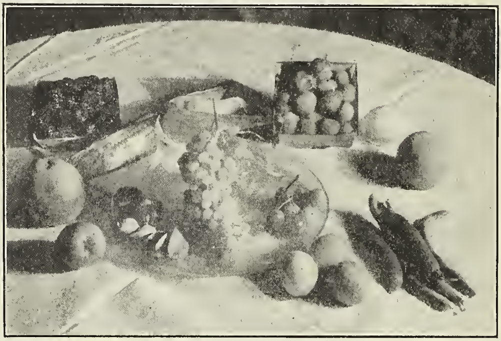
Foods of plant origin. Select five foods containing a high percentage of protein, five with a high percentage of carbohydrates, five with a high percentage of water. Do vegetable foods contain much fat? Which of the above-mentioned foods have the highest fuel value? Which contain vitamins?



Foods largely of animal origin. Compare with the previous chart with reference to amount of protein, carbohydrate, and fat in foods. Compare the fuel value of plant and animal foods. Compare the relative percentage of water in both kinds of foods. Are vitamins as abundant as in plant foods?

The kinetic energy they got from the sun is simply transformed and locked up in these foods. Food supplies which were formed by the green leaves are sources of potential energy until used.

Foods Made in Leaves Are Stored Elsewhere. Another thing you will notice about plant foods is that while they were mostly made in the leaves, leaves do not make up a large part of our food. Cattle and other grass-eating animals use leaves, but man usually eats the fruits, such as grains, nuts, or fleshy fruits like apples, pears, bananas, grapes, and the fruits we call vegetables, such as squash, corn, or tomatoes. Or we eat the roots, like radishes, beets, carrots, and parsnips, or a few stems, such as asparagus and the potato; which is an underground stem. Evidently, then, the food made in the leaves must be transported and stored in other parts of the plant.



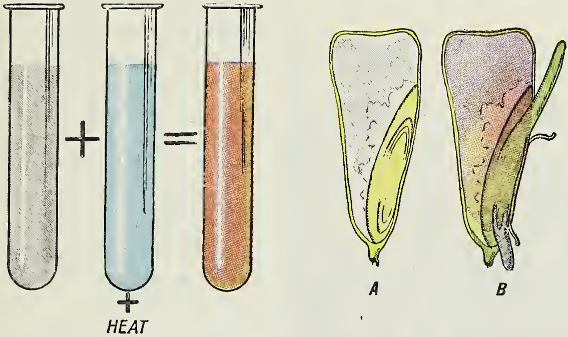
Wright Pierce

How many fruits shown here can you name? What fruits in your locality can you add to this collection?

Foods Are Transported Largely as Sugars. Have you ever tasted the sap which will ooze from a cut tree trunk in the spring? If so, you must have noticed its sweet taste. The carbohydrates are sent from one part of the plant to another in the form of sugars because sugars are more soluble than starch. One form of sugar found in plants is called grape sugar. Since it is often a product of digestion of starches, we find it convenient to have a test for it. The following is the test for this substance.

Demonstration 4. Test for Grape Sugar.

Place a small amount of the substance to be tested in a test tube of water. Add to this an equal amount of #1 and #2 Fehling's solution.[1] The mixture now has a deep blue color. Heat gently. If grape sugar is present, the contents of the test tube will turn brick red.



Test for grape sugar. What solutions are in the first two tubes? Explain meaning of tube three. Explain *A* and *B*.

Why Some Foods Contain Proteins. We found, however, that some plants, noticeably the legumes, contain a large amount of protein. Why is this, we wonder. Again let us think back and we will recall that the legumes had as helpers certain bacteria which were lodged in little swellings on the roots. These bacteria, you remember, were able to take free nitrogen from the air and fix it so that it could be used by plants. Is it any wonder, then, that with this extra supply of nitrogen the legumes should have a larger supply of proteins stored up than the other plants? For protein has the element nitrogen in its composition as well as carbon, hydrogen, and oxygen, the latter three elements only being found in carbohydrates and fats and oils.

There are other plants which form protein foods, such, for example as many nuts, which are rich in both oils and proteins. The avocado, and the grains out of which we make our breads and cakes, all contain protein.

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[1] Fehling's solution is prepared in two parts. For #1, dissolve 35 grams of copper sulphate in 500 cc. of water. For #2, dissolve 160 grams of caustic soda and 173 grams of Rochelle salt in 500 cc. of water. In testing, add equal parts of solutions #1 and #2.

What Plants Are the Chief Sources of Our Food Supply? *Corn.* When we state that the United States produced over 3,600,000,000 bushels of corn and wheat in 1932, it does not mean much except a vast amount of cereal crop. But when we say that this country produced over $\frac{3}{5}$ of all the corn raised in the world and about $\frac{1}{6}$ of all the wheat, then we see the importance of cereal crops. Most of the corn goes to feed hogs and cattle, thus giving us the saying "corn on the hoof." But we do use some of it as corn meal, breakfast foods, and corn starch as well as to make sirup and canned corn.

Sugar beets.

Wheat. Wheat, on the other hand, is a great staple. We use in this country about 6 bushels per capita, a matter of some 750,000,000 bushels a year. Kansas is our greatest wheat-growing state. Its yield was badly depleted in the memorable drought of 1934.

Other Grains. Other grains, such as rice, barley, rye, and buckwheat, play a more important part in other countries than in ours. The United States, however, ranks first in the production of oats. Although we use oats as oatmeal and in prepared cereals and crackers, most of our oat crop is fed to animals.

Sugar. Sugar is an important food, giving us nearly 20 per cent of our total calories of energy. This country has a sweet tooth, for it uses at present about 103 pounds a year for every man, woman, and child in the United States. We produce a good deal of our sugar both from sugar cane, which is grown largely in Louisiana, and from sugar beets, which are produced in large quantities in Colorado and other western states. We also get maple sugar from the sap of the sugar maple tree.

Vegetables. Other important food products are potatoes, of which there were over 3,300,000 acres under cultivation in 1932, yielding over 350,000,000 bushels. To this crop we can add nearly 80,000,000 bushels of sweet potatoes. When we add to this a total of about $350,000,000 worth of vegetables grown in the home gardens for home consumption and some 1,600,000 acres of truck farms which raise vegetables for sale in markets or to canneries, we realize the magnitude of the plant food supply in this country.

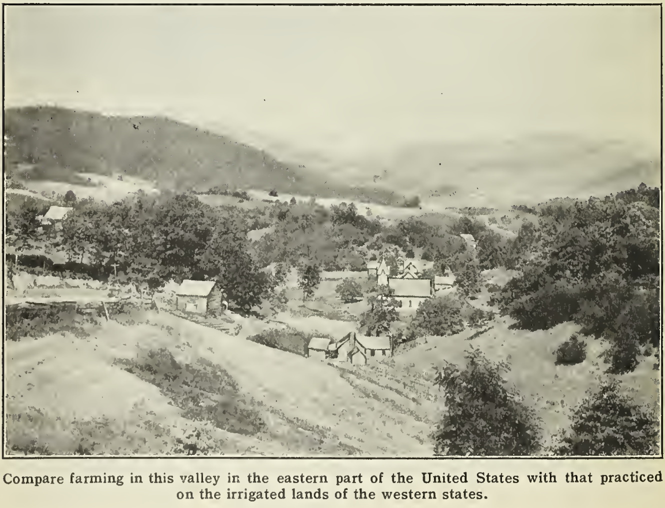
Fruits. But we still must add fruits to the list. They are important in man's diet because of the vitamins they contain. Apples, pears, peaches, grapes, plums, prunes, melons, and berries of many kinds are the products of the orchards and vineyards of our temperate climate. Then we have another very important group of subtropical fruits raised in this country, the citrus fruits. Of these, oranges, lemons, and grapefruit are most important.

Agriculture as a Vocation. We hear a good deal of discussion nowadays about the life of the farmer and his place in society. We certainly cannot get along without the farmer, for from his vocation comes our food supply. There are well over 10,000,000 people engaged in agriculture and crops and prices fluctuate. The gross incomes from farms all over the country have been above $16,000,000,000 a year, but went down to less than a third of that amount in 1933. Yet agriculture is still the largest industry in the United States.

Types of Farming Communities. Since most farms are of large size, some several hundred acres, the houses are scattered. Machinery does much of the work and each large farm is often the center of more than one family. Farming communities are well-to-do. The farmers have their own automobiles, and the villages are often settled by retired farmers. Stores keep commodities which are needed for tilling and reaping, also those staple foods which cannot be grown on the farm. Doctors and dentists and other professional men locate in these communities. There are good churches and schools and movies, and the post office provides rural delivery. There are no very poor nor very wealthy people, thus a farming community in many respects is ideal.

Wright Pierce

A California fruit orchard in bloom. Do you know what kind of trees these are? Where does the water come from to irrigate such orchards?



Compare farming in this valley in the eastern part of the United States with that practiced on the irrigated lands of the western states.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

fruits
carbon
grains
fats
roots
transported
energy
kinetic
oils
wheat
radiant
vitamins
hydrogen
sugar cane
oxygen
proteins
plant
water
sun
citrus
corn
beets
nitrogen
carbohydrates
leaves
green
potential
matter

Green plants are the largest sources of our (1)____ producing foods, the (2)____. The (3)____ energy received from the (4)____ is changed and stored as (5)____ energy in the (6)____. Foods, although made in the (7)____ or other (8)____ parts of the plant, are (9)____ and stored in (10)____, stems, and especially in the (11)____. While plants make largely (12)____, they do form (13)____, oils, and (14)____ as well. Most plant (15)____ come from the legumes which support bacteria on their roots. The bacteria fix (16)____ from the air. Many plant (17)____ are not as good as animal proteins for making living (18)____. Our largest sources of plant foods are the (19)____, especially (20)____ and (21)____; sugar, which comes principally from (22)____ and (23)____. The citrus fruits have become of great importance of late years because of the (24)____ they contain.

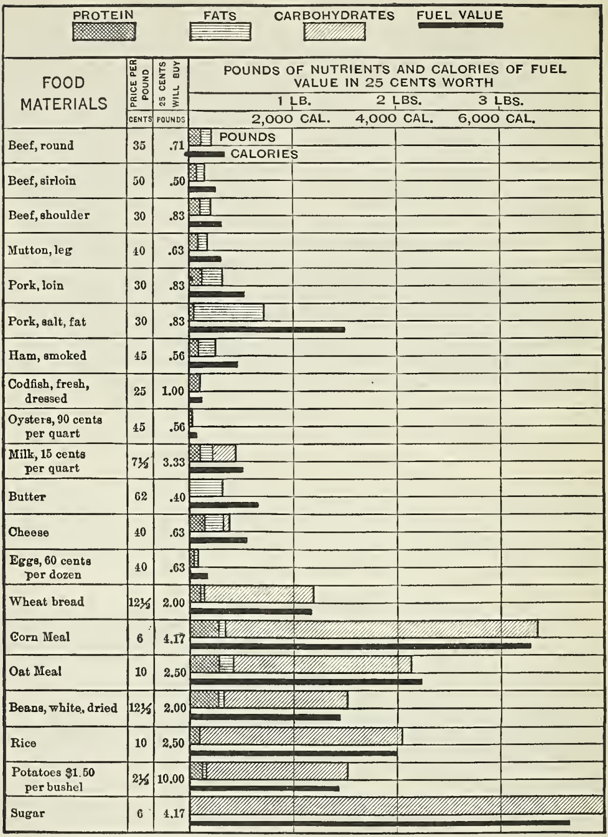
PROBLEM TEST

Using the graph on page 510 and prices given, answer the following questions:

1. If you wish to get your money's worth of proteins, which of the foods shown would you select?
2. If you wish a cheap energy-producing food, which would you select?
3. Why are some of the foods shown expensive?

PROBLEM III. WHAT ARE THE SOURCES AND USES OF ANIMAL FOODS?

Animal Foods Contain Much Protein. If you will look at the charts on pages 502 and 503, you will find that one great chemical difference exists between animal and plant foods. While the latter are sources of much of our energy, animal foods have relatively larger amounts of protein and hence are growth foods. Their fuel value comes largely from the fats.



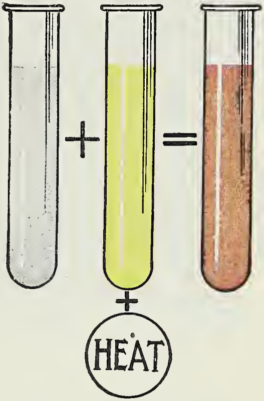
FOOD MATERIALS	PRICE PER POUND CENTS	25 CENTS WILL BUY POUNDS
Beef, round	35	.71
Beef, sirloin	50	.50
Beef, shoulder	30	.83
Mutton, leg	40	.63
Pork, loin	30	.83
Pork, salt, fat	30	.83
Ham, smoked	45	.56
Codfish, fresh, dressed	25	1.00
Oysters, 90 cents per quart	45	.56
Milk, 15 cents per quart	7½	3.33
Butter	62	.40
Cheese	40	.63
Eggs, 60 cents per dozen	40	.63
Wheat bread	12½	2.00
Corn Meal	6	4.17
Oat Meal	10	2.50
Beans, white, dried	12½	2.00
Rice	10	2.50
Potatoes $1.50 per bushel	2½	10.00
Sugar	6	4.17

Table showing the cost of various foods. Using this table, make up an economical dietary for one day, three meals, for a man doing moderate work. Give reasons for the amount of food used and for your choice of foods. Make up another dietary in the same manner, using expensive foods. What is the difference in your bill for the day?

How to Test Foods for Proteins. If you wish to prove the presence of protein in food, the following test is useful.

Demonstration 5. Test for protein.

Add a few drops of strong nitric acid to the hard-boiled white of an egg. Rinse the acid off with water and add ammonia. The lemon color of the egg after the addition of the acid and the deep orange following the addition of the ammonia is the test for proteins.



Other simple tests for animal proteins are the burning test and the heating test. If a substance contains protein, it will give off an odor like burnt feathers when it is burned. A semifluid substance can be tested for protein by heating. If protein is present, it will coagulate as does the white of an egg when it is heated.

Water Is Present. Of course water makes up a very large part of animal foods, as well as plant foods. The amount can be determined by weighing the substance, then heating it until it is completely dried out, and then reweighing. The difference will be the amount of water present. Water forms a very large part of the human body, in fact about 65 per cent.

How Do Animals Get Their Proteins? Of course this question is easily answered in the case of the flesh-eating animals like cats, dogs, lions, tigers, or man. The fleshy foods that are eaten are digested, taken into the blood, and sent to the cells. There the proteins may be oxidized just as any other food and energy released. But they have much the same chemical make-up as does the living stuff out of which the body is made. So the cells take most of these digested proteins and rebuild them into the body. In the case of the animals which feed upon plants, a similar happening must take place. Plant cells have the same living stuff as do animal cells; the chemical make-up is practically the same in both cases. So it is not difficult to see how the plant-eating animals get the proteins necessary to build up their cells. However,

Wright Pierce

A roundup in the high Sierras. What will become of these cattle?

animal proteins are apparently more easily used for this purpose than are plant proteins, some of which do not have the necessary chemical composition to form the flesh and blood of animals.

What Are Some of the Sources of Our Animal Food? To answer this question, we at once think of the great grazing lands of the Middle West, of cowboys and of herds of cattle. It was estimated that in 1930 there were over 47,000,000 head of cattle usable for food, and nearly 17,000,000 dairy cows in this country. The total value of these was estimated at over $3,000,000,000. It is probable, however, that a census taken after the drought summer of 1934 would show these figures considerably reduced. The census also reports that in 1931 there were nearly 57,000,000 sheep and over 56,000,000 hogs, with a total value of over $1,000,000,000. This looks like food enough for a nation. In addition to this source of food, we must take our domesticated fowls, turkeys, and ducks, as well as their eggs. All of these give a huge source of food which is largely protein.

What Are the Sources of Our Fish? To anyone who fishes for sport, the thrill of fly-fishing a trout brook and of hooking an occasional big one is something not easily forgotten. But commercial fishing is quite another matter. In the first place, most

Galloway

A Colorado sheep range. What kinds of regions are used for sheep grazing?

of our food fish are salt-water fish, although we do have very valuable fisheries for lake trout and whitefish in the Great Lakes. But the chief fishing areas are the waters of the continental shelf which contain the so-called "banks" off Newfoundland. Most fish live either upon smaller fish, upon animals living on the bottom, or on the small floating plants and animals known as *plankton*. This latter food is found only in relatively shallow water or near the surface of large bodies of water. The continental shelf, where the water is rarely over 500 to 600 feet deep, provides food for fish like the cod, haddock, halibut, and mackerel, and so they are found there in great numbers. On the western coast, the salmon industry employs thousands of men and hundreds of boats. The total value of the salmon caught for 1932 was nearly $25,500,000 and that of all the fisheries exceeded $77,000,000.

Fish as Food. Fish and shellfish make a particularly good food, although some of them are expensive because of the large amount of water they contain. They are not brain foods as are popularly supposed, but they do have another important use. The human body needs a small amount of iodine to be supplied at

Gabriel Moulin

Fishing boats in Monterey Bay, California. Why are these boats anchored here?

Asahel Curtis

Salmon fishing. Drawing up the nets. No wonder the salmon are rapidly disappearing. What would you suggest to protect these fish?

intervals if we are to be healthy. This iodine can be obtained from the bodies of animals that live in salt water, for they get a supply of iodine in their food. Therefore salt-water fish, oysters, clams, lobsters, crabs, and shrimps all make excellent sources of this important element. If you cannot get fresh fish, canned salmon has been found to contain iodine. Canned oysters and clams also contain it. Cod and halibut are sources of vitamin D, so essential to our well-being.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

1932
living
salts
water
$50,000,000
$4,000,000,000
$100,000,000
1926
protein
plant
$2,000,000,000
$80,000,000
iodine
proteins
body

Animal foods contain more (1)____ than most (2)____ foods. They also contain large amounts of (3)____. Animal (4)____ are more useful to make living material in man than are (5)____ proteins, some of which cannot be transformed into (6)____ matter in the (7)____. Most of our (8)____ foods come from cattle, sheep, and hogs. These animals have a total annual value of over (9)____. Salt-water fish make excellent food because of the (10)____ they contain. The fisheries of this country totaled nearly (11)____ in value in (12)____.

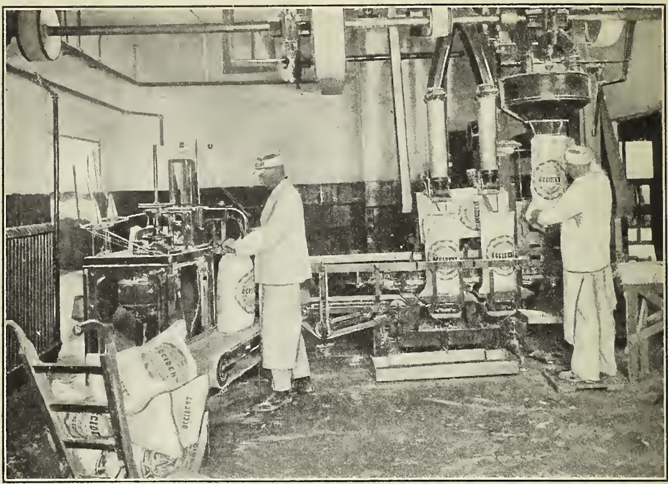
PROBLEM TEST

Use text and charts on pages 502 and 503 to answer the following questions:

1. Why do we say that animal proteins are usually better than plant proteins?
2. Which of the foods shown are the cheapest sources of proteins?
3. Which of the foods shown are the *best* sources of proteins?

PROBLEM IV. HOW ARE FOODS MANUFACTURED AND DISTRIBUTED?

Industries That Depend upon Agriculture. Have you ever thought of all the occupations and industries that depend upon agriculture? Crops and livestock form a large part of the freight carried by the railroads. The milling of flour, the manufacture of



Galloway

What stage of the milling process do we see here?

breakfast foods, the drying and canning of fruits and vegetables, the storage and distribution of cold storage products, the marketing of the various products, these and many more vocations depend in the long run upon the farmer.

The Milling Industry. In early colonial days, mills for grinding wheat and corn were located on streams where water power was available. Today the country's largest milling centers are at Minneapolis, Minnesota, and Kansas City, Kansas, both because of the water power available and nearness to wheat fields, and at Buffalo, New York, where wheat can easily be shipped by boat. But because of the ease with which wheat can be transported, great elevators for its storage are found in Chicago, Buffalo, Duluth, Seattle, and other cities which mill and ship wheat. The old process of grinding wheat by using millstones has given way to a process in which corrugated rollers are used to crack the wheat grains. By this method, the grain is gradually reduced to a powdery flour, and the impurities are gotten rid of by screening and blowing devices so that about 75 per cent of the grain is used. Many kinds of flour are bleached to make them white.

Prepared Cereals. In this country there has come to be a great demand for ready-cooked breakfast foods. Instead of hot oatmeal or cream of wheat, we like to eat various foods made of partially cooked or completely cooked grains or malted preparations in which part of the starch is changed into sugars. The chemical composition of such foods shows that they are changed very little from the original wheat or corn from which they are made, but are much more expensive than the uncooked cereals. They do give variety to our diet and they save the expense of cooking. In addition to making prepared foods, we have the baking industry. The bakeries of our country make over $1,000,000,000 worth of bread, cake, and crackers each year. The largest number of bakeries are located in the cities.

The Canning Industry. The process of canning dates back to the time of the Napoleonic wars when a prize was offered by Napoleon for a method of preserving food for his armies on the march. In the modern canning factory, the tin cans are coated on the inside with a lacquer which prevents acid fruits or vegetables from dissolving any of the tin. The food is either sterilized inside the cans or is put into the cans hot and then heated above

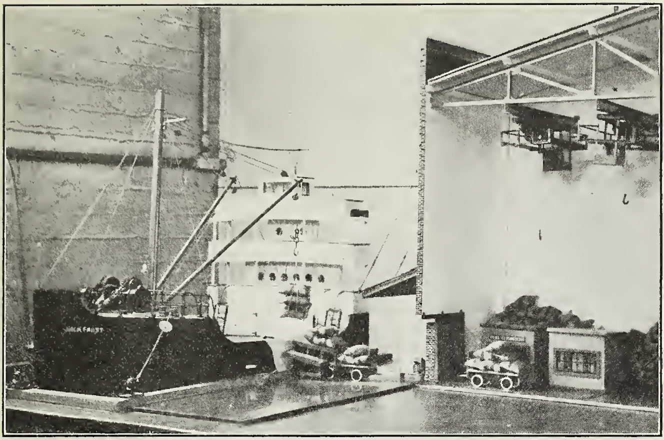
Hawaii Tourist Bureau

A canning factory in Hawaii. What food products are canned there?

Drying is one of the important methods of preserving foods. What story does this picture tell you?

the boiling point for a long enough period not only to kill bacteria but also their spores. The modern can is sealed by machines which make a tight joint when the can is spun on the closing machine. Two relatively small areas, one in California and another between Baltimore and New York, put up over half of this country's canned goods. This is because of their proximity to truck gardens and orchards which produce materials for canning. The canning of meats centers around the great slaughtering plants at Chicago, Kansas City, and Omaha. The canning of milk and milk products centers away from large cities, but near the source of production. Wisconsin, Minnesota, and Iowa furnish most of our canned milk. The fish-canning industry, because of the salmon, tuna, and sardine fisheries, is largely confined to the Pacific coast. But the eastern seaboard also preserves a good share of the lobsters, oysters, and clams, as well as many salt-water fish. The drying of salted fish is also a large industry. Gloucester, Massachusetts, is an example of a city largely devoted to this industry.

Sugar Manufacturing and Refining. Two processes are used in the refining of sugar, one the grinding and crushing of the cane

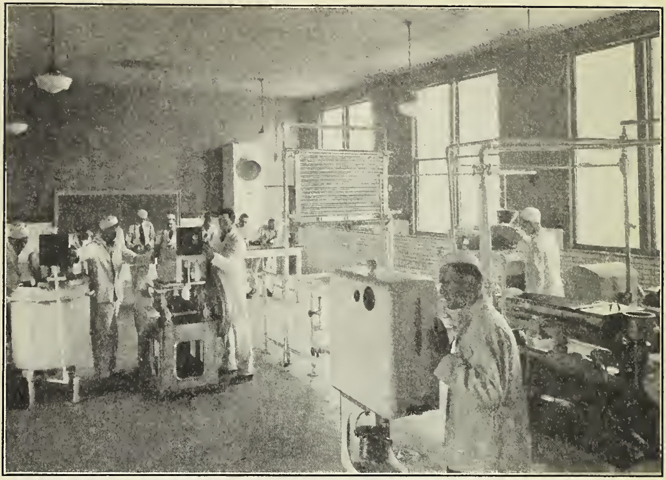


Unloading sugar boats. Where do we get most of our sugar from?

or stalks from which the sugar is made; the other, called the "diffusion process," is used in extracting sugar from beets. Raw cane sugar is brought in ships from the tropics where it is grown to New York, Boston, Philadelphia, San Francisco, and other large cities to be refined. This is done by passing a solution of the raw sugar through bone-black filters which take out the impurities and give it the white color.

The Luxury Industries. These so-called luxury industries which depend on agriculture for their existence are the manufacture of ice cream, chocolate, and candy. These industries center quite largely in the eastern part of the country and are located in or near large cities. The people of New York City consume over 11,000,000 gallons of ice cream every year. Ice cream is manufactured in large amounts in cities that have hot summers and do not feel the cooling influence of ocean breezes. It is said that in the area which composes Pennsylvania and parts of Ohio, New York, and Massachusetts, a family of five spends $40 or more a year for ice cream, one third as much as they spend for bread.

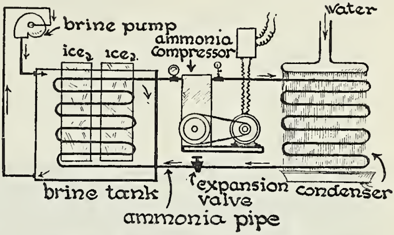
The Transportation of Perishable Foods. It is only of late years that we have been able to enjoy fresh vegetables and fruits



A modern ice-cream plant. Do some outside reading about how ice cream is made on a large scale.

far from the places where they were grown and long out of season. But with the discovery of refrigeration and cold storage and the more recent uses of "dry ice," it is possible not only to send perishable vegetables from distant points by rail or boat, but also to keep them for long periods of time so that we can now get fruits and vegetables in the winter for very little more than they cost in the summer. This is brought about by the cold storage industry.

How Artificial Ice Is Made. You have all seen the frost-covered cooling pipes in a large market and have doubtless wondered just how this cold was obtained. The process of making artificial ice by the use of ammonia gas is at the basis of the cold storage industry. If we take liquid ammonia at any pressure above one atmosphere and decrease the pressure, the liquid ammonia will change to gas, absorb heat, and lower the temperature. As the ammonia changes to vapor, it rapidly produces a temperature low enough to make ice. Ammonia gas is forced into cooling pipes under pressure and by repeated compression strokes of the pump is liquefied in coils of pipes. As it becomes liquid, it gives off heat which is removed by sprays of water outside the pipes. These cooling pipes are connected with more coils of pipe which are placed in a great tank of brine or salt water. The liquid ammonia passes through a valve, which can be controlled, into these pipe coils in the brine. To these coils is connected the exhaust pump. During the expansion stroke of this pump, a partial vacuum is created inside the cylinder and the ammonia gas moves from the coiled pipes in the brine into the pump. As the pressure in this coiled pipe is diminished, more liquid ammonia becomes vaporized. Both the changing of the liquid ammonia to a gas and the expansion of the gas absorb heat from the brine which may thus be cooled to any temperature. Metal cans, each of which holds 300 pounds of water, are lowered into the brine and freeze, producing artificial ice. In many cold-storage warehouses the cold brine is pumped through pipes around the walls of rooms where foods are stored. The degree of cold is automatically kept at the right temperature for the food in each room.

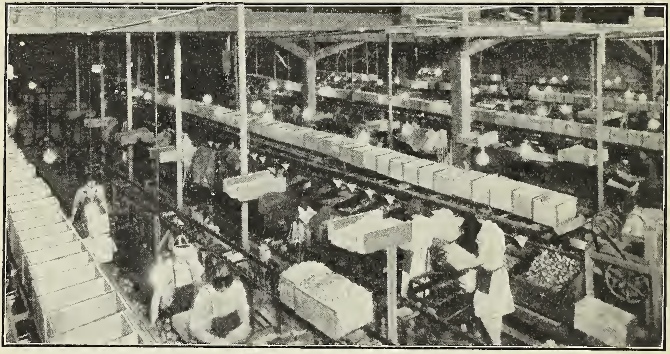


Read your text and then explain this diagram.

Dry Ice Refrigeration. A new refrigerant known as dry ice is solid carbon dioxide. While it has not come into very general use, it has a great future use in shipping because it occupies so little space and lasts so much longer than ordinary ice. It takes 17,000 pounds of ordinary ice and 1200 pounds of salt per car to send a shipment of frozen fish from New York to Detroit. It takes only 1200 pounds of solid carbon dioxide for the same trip and there is no expense of re-icing.

Quick Freezing. Fresh foods, as fruits, fish, and meat, may be frozen, and if kept frozen until time for use, they preserve their quality of freshness. The secret of preserving their natural properties is to freeze them quickly. When water freezes slowly, the crystals of ice formed are large, while in intense cold more crystals but finer ones form. In quick freezing the cell walls and tissues of foods are not ruptured as they are in slow freezing. Foods placed in packages are run through refrigerating machines where temperatures of −10° F. or lower are maintained. These foods must be kept at a temperature below freezing during transportation and storage until purchased by the consumer.

Marketing of Foods. Here we have a very large industry depending again on agriculture as a basis. Do you realize that our food stores sell over $10,000,000,000 worth of goods in a good year? Much more in value than any other industry. Great organizations exist for marketing the crops, such as the Citrus Growers Associations of Florida and California, or the co-operative associations of farmers in many states. Florida, for example, produces 75 per cent of all the grapefruit, while California grows two thirds of all oranges and nearly all the lemons raised in the United States. They must have adequate organizations to sell these products at the very best prices. All along the line from the time the product leaves the farm, vineyard, or orchard, think of the people employed in selecting, picking, sorting fruits or vegetables, wrapping, packing, distributing by trucks, wholesaling, and selling the products in the retail markets. The sun certainly sets in motion a long sequence of events when its energy causes the making of many foods used by man in the green leaves of plants!



Asahel Curtis

An apple-packing plant in central Oregon. How are apples produced in this near-desert region?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

monoxide
25 per cent
agriculture
cook
grain
storage
raised
sugar
flour
water
prepared
mining
dioxide
perishable
cold
hot
expensive
milling
75 per cent
meat
dry
50 per cent
fish
fresh
season
luxury
seasonal
crushing
quick
unprepared
industry

Many industries, as milling, canning, sugar manufacture, cold storage, and others, depend upon (1)____. The milling industry uses a (2)____ process in making (3)____ which makes use of about (4)____ of the (5)____. The (6)____ cereal foods (7)____ has grown to great proportions. We do not have to (8)____ them, but they are much more (9)____ than the same cereal in an (10)____ form. The canning industry largely depends on (11)____, although very large amounts of (12)____ and (13)____ are canned. The so-called (14)____ industries of ice cream making, candy and chocolate manufacture depend again upon (15)____, as does (16)____ manufacture and refining. Since many agricultural products are (17)____ and do not keep well, the (18)____ (19)____ industry has come out of the need to deliver (20)____ vegetables and fruits long distances from the place where they were (21)____ and out of (22)____. Artificial ice is much used for refrigeration, but solid carbon (23)____ or (24)____ ice and (25)____ freezing are coming into use quite rapidly.

PROBLEM TEST

Some people object to cold storage foods and artificial ice produced by the ammonia process of refrigeration.

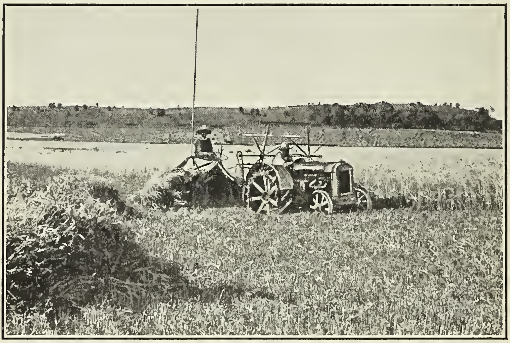
Which of the following do you think are valid reasons for these objections?

1. The process is dangerous; if a pipe bursts a workman may suffocate from ammonia fumes.
2. Artificial ice has ammonia in it.
3. Artificial ice has less cooling power than natural ice.
4. Ice does not kill germs.
5. Frozen foods generally spoil more quickly after taking out of storage than they would have if they were fresh.

6. Spoiled foods are sometimes frozen to keep them.
7. Fish and meats from cold storage taste of ammonia.
8. Because of the cost of cold storage, cold storage foods are more expensive than fresh foods.

PROBLEM V. WHAT ARE WE DOING TO PROTECT, CONSERVE, AND INCREASE OUR FOOD SUPPLIES?

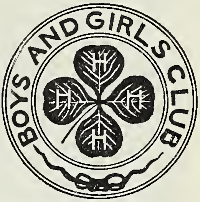
The Present Plight of the Farmer. We have already seen some of the ways in which individuals and national agencies are working out methods of conservation of our natural resources. Let us now see what is being done to conserve and increase the domesticated plants and animals which form the sources of our food supplies. Just at present the farmer is having a hard time, for food prices have been down, owing to overproduction, although they are now rising again due to crop shortages. The value of farms has shrunk from over $66,000,000,000 in 1920, to about $30,000,000,000 in 1933. While his property has decreased this much in value, his taxes and mortgage payments and machinery costs have been increasing and the prices he got for his commodities have been decreasing. The depression has kept many young people from going to the cities to work, so that the farming population is now greater than ever before. Over 32,000,000 people were living on farms in 1933, according to the United States Department of Agriculture surveys. So the farmer has more mouths to feed with



A good yield of wheat results from favorable weather conditions and good management.

less income to do it with. It is evident that everything that science can do to help the farmer should be done. Let us see what is being accomplished.

Public Agencies at Work to Aid the Farmer. These agencies are of two kinds, private and public. The public agencies may be either state or federal. The United States Department of Agriculture has several definite agencies at work in its experimental stations, its Bureau of Soils, its Department of Entomology, its Agricultural Extension Service and its home economics work which reaches the boys and girls through the 4-H Clubs and other activities.

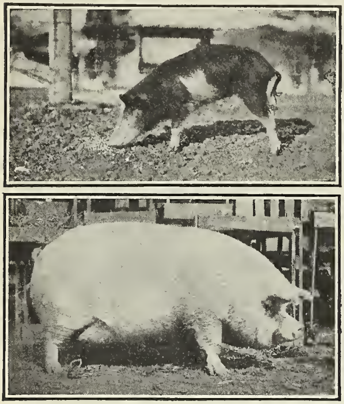


The 4-H emblem. What are the meanings of the four H's?

In the 4-H club emblem the first H stands for the head and clearer thinking; the second H for the heart and a greater loyalty; the third H for the hands to a larger service; and the fourth H for health and a better living for the club, for the community, and for the country. The clubs are sponsored under the Smith-Lever Act, which established a state agricultural extension service. The 4-H Clubs have been established in hundreds of rural communities and are training leaders for the future in these places.

Then we have the work done by the Reclamation Service of the Department of the Interior and their reports. The various states also have their agricultural departments which operate experimental stations and send out field workers to help the farmers. State universities operate schools of agriculture at which boys expecting to go into agriculture can get training in the latest and best methods of scientific farming. In addition to these public agencies, many private colleges and universities have members of their staff at work on problems of inheritance and disease prevention which can be applied practically in agriculture. Farmers' Co-operative organizations are doing much to help in getting a fair price for farm products.

What Is Being Done in Improving Plants and Animals? As we have read in previous units, most of the work is centered around the knowledge of the laws of heredity. The Bureaus of Plant and Animal Industry of the Department of Agriculture are the agencies which do most of the work. Plants are bred for resistance and immunity to disease, as, for example, resistance to rust in wheat, or blight in potatoes. Resistance to drought conditions has been bred in wheat or hardy varieties of wheat that will ripen early and thus escape rust which comes late in the summer have been found. Such is the famous Marquis wheat, which today is being planted over 15,000,000 acres in Canada and the northern United States. It was produced by crossing an early ripening wheat called Red Calcutta with the Red Fife, a wheat that has a very high yield. Other cereals, as corn, have been bred to produce a greater yield of protein or oil, for size of kernels or size of the ear. Fruits of various kinds are improved by hybridization so that we have greater size, better color, or more delicious flavor.



U. S. Dept. of Agric.

The modern pig has been developed from a small, wild form.

Animals have been improved tremendously, especially our cattle and hogs. Cows are bred for milk production and butter fat, a single animal having a record of over 32,500 pounds of milk and 1600 pounds of butter in a year. It has been estimated that in the past 30 years the Jersey cow has been bred so that it now produces three times the amount of butter fat that it did formerly. Hogs are improved from the old type of "razor back," which rarely weighed more than 150 pounds, to the average market hogs, which weigh 400 pounds, and the prize hogs which weigh over 1100 pounds. Horses have been bred for speed or strength, sheep for quality of wool and quality of flesh, poultry for egg production. All of the information with reference to plant and animal breeding is available to the farmers through the publications of the Bureaus of Plant and Animal Industry and by the field workers sent out by the Department of Agriculture.

Department of Agriculture Building in Washington.

Work of the Bureau of Soils. This bureau spends much time and money in experimenting in the uses of different soils by the farmers. Advice is given on many subjects concerning the kinds of crops that will grow best in a given soil, on the acidity or kinds of mineral substances to be found in different soils, on the uses of fertilizers or mineral salts, on the relation of the soil to fungus growth on crops, and many other matters. This bureau, together with the Reclamation Service of the Department of the Interior, gives much free advice to settlers buying new lands in irrigated areas.

Work of the Bureau of Entomology. The harm done by insects to the crops of the nation is estimated to be over $1,500,000,000 a year, or at least a tenth of our crops. We have already seen some of the ways in which this bureau is working to keep down insect pests, most of which have been imported with the very plants that man wished to improve. There are several ways in which this bureau is active. It suggests methods of control of pests by spraying or use of contact poisons and does this through knowledge of the life habits of each parasitic insect. A bug, for example, sucks the juices of plants and must be fought with a poison that will clog its breathing pores, such as a nicotine or oil emulsion. On the other hand, a biting insect, like the caterpillars or beetles, would be fought by spraying its food plants with poisons. Other methods such as completely changing the crops have also been recommended. These changes have resulted in many southern states in growing crops of vegetables rather than cotton, which was being destroyed by the boll weevil. And most important is the work done in finding the natural enemies of these imported pests. We have spoken of some of these examples in another unit (see pages 421–422).

Fumigating citrus trees in California. Why is fumigation with a deadly gas superior to other methods of killing certain insect pests?

How the Results of Science Are Brought to the Farmer. In general there are two ways: the Department of Agriculture prints a great number of different Farmers' Bulletins for free distribution. These can be obtained by writing to Washington, giving the number of the desired bulletin. These and many other publications can be obtained free from the Department of Agriculture and the Department of the Interior. In addition, a person may write and make personal inquiries and be sure of a reply to his questions. Then a new extension service was inaugurated in 1933 in which demonstration agents of the United States Department of Agriculture and the various state agricultural colleges bring to the farmers and their children the latest information with reference to the economic situation as it relates to agriculture in their particular locality. Not only does this service deal with the economic side, but it also is related to farming. In one county in South Dakota a yearly loss of $76,000 from grain smut was wiped out; in Delaware the sweet potato growers in one county reduced their loss caused by stem rot from over 30 per cent to 2 per cent. These are illustrations of only a few cases.

Spraying apple trees.

Work of the Farmers. All of these governmental agencies would be of little value without work on the part of the farmer. Everywhere we see new methods of growing and marketing being used; everywhere the farmers are coming to see the value of science in crop production. An example of this is seen in the citrus industry of California and Florida. Not only is the greatest care taken in fertilizing and irrigating the ground, but the groves are sprayed and fumigated each year so as to reduce the insect pests. In the winter the United States Weather Bureau maintains a radio frost service to warn the growers of approaching frosts. On cold nights the groves are bright with the fires from thousands of "heaters," the use of which has reduced the loss to almost nothing each year. Once the oranges are ready for picking, they are taken to co-operative packing plants where each orange is washed, sorted in lots of different sizes, stamped and wrapped to be packed and shipped in refrigerator cars to all parts of the United States. This is only one example of the care necessary in raising crops scientifically.

Heaters in a California orange grove. What fuel is used?

Science plays its part in every kind of agricultural or animal industry. Each year our plant and animal products become better, the production of crops per acre increases, the yield of milk, butter, or eggs is greater and richer, and all because of the co-ordinated work of the scientist and the farmer.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

better
publications
colleges
entomology
poorer
smaller
practical
help
living
investigations
experiment
agriculture
soils
crops
agents
plant
farms
rivers
field
harm
results
state
department
bulletins
industry
economic
government

At present there are more people (1)____ on (2)____ than ever before with a (3)____ return to the farmer from his (4)____. This is caused by the (5)____ situation and not because the crops are (6)____. Many agencies (7)____ the farmer; chief of these are the Bureaus of (8)____ and Animal (9)____, the Bureau of (10)____ and the Bureau of Entomology of the United States (11)____ of (12)____. The (13)____ departments of agriculture also have many (14)____ stations and agricultural (15)____.

PROBLEM TEST

A farmer has found an unknown insect eating his ears of corn. He thinks it may be the European corn borer. What should he do?

Select from the list below enough sentences to completely answer this question.

1. Many insects eat corn. It will probably not come back next year.
2. He lives beyond the area known to be infested by the European corn borer.
3. He should proceed to kill all he can by the best means he can find.
4. He should say nothing about the pest to his neighbors for fear of disturbing them.
5. He should at once write to his nearest state experiment station and send them specimens of the insect.
6. He should study its methods of feeding and use poison on it.
7. After hearing from the experiment station he will read the literature they send and act on the advice found therein.

◆

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. These are some of the generalizations that we should use in making our review summary:

1. Green leaves make food, using energy from sunlight.
2. Sugar is first made, later starch and other foods.
3. Sugar is made out of carbon dioxide of the air and soil water.
4. Food is made only where chlorophyll is present.
5. Sunlight and a favorable temperature are necessary.
6. Food made in leaves is transported to and stored in roots, stems, and fruits.
7. Many occupations, such as milling, food manufacture, canning, cold storage, and marketing, depend upon the work of plants.
8. The state and national governments have many agencies to help the farmer to better production.
9. The betterment of food plants and livestock comes through a knowledge of the laws of heredity.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT, *write numbers of all statements you believe are true. In another column under* INCORRECT, *write numbers of untrue statements. Your grade = right answers × $2\frac{1}{2}$.*

I. **Green leaves make food**: (1) when the sun shines; (2) all the time; (3) only in warm weather; (4) at night; (5) when they are separated from the plant.

II. **Sugar is made in the green part of the leaf**: (6) when carbon dioxide and water get into the cells containing chlorophyll; (7) and in all cells of the leaf; (8) starch being made at a later stage of food making; (9) only if the temperature is favorable; (10) only when sunlight falls on the cells holding the chlorophyll bodies.

III. **The plant gives off the following substances during the process of starch making**: (11) air; (12) water; (13) heat; (14) oxygen; (15) carbon monoxide.

IV. **Food for man is found in**: (16) roots; (17) stems; (18) leaves; (19) flowers; (20) fruits.

V. **Plant foods are indirectly used by man**: (21) when we eat oysters; (22) when we drink milk; (23) when we eat beefsteak; (24) when we drink a soda; (25) when we eat eggs.

VI. **The following industries depend directly or indirectly upon green plants**: (26) making ice cream; (27) making artificial ice; (28) railroads; (29) canning; (30) milling.

VII. **Ice**: (31) is useful because it gives off heat when it melts; (32) can be made of carbon dioxide; (33) is manufactured in quantity by the use of ammonia under pressure; (34) is used in refrigerator cars for shipping fresh fruits and vegetables; (35) keeps longer than dry ice.

VIII. **The United States Department of Agriculture**: (36) has a Bureau of Soils; (37) runs the Reclamation Service; (38) uses the latest experiments in heredity to produce better plants and animals; (39) has supervision over our National Parks; (40) puts out free Farmers' Bulletins.

PRACTICAL PROBLEMS

1. How many examples can you find in plant and animal breeding where the workers have used Mendel's laws?

2. Can you devise an experiment to prove that sunlight is necessary for the work of a green plant?
3. Take some plant or animal that has been domesticated for a long period of time and trace the changes that have taken place since man began to domesticate it.
4. Prove that the sun is the source of energy which makes it possible for me to write these words.

LEISURE TIME ACTIVITIES

1. Visit some industry directly connected with agriculture and make a report on it.
2. Visit an industry that indirectly depends upon agriculture and report on the visit to the class.
3. Make a collection of pictures showing phases of industry in your own locality that depend directly or indirectly upon green plants. Exhibit your collection on the bulletin board.

SCIENCE CLUB ACTIVITIES

1. Organize a meeting to discuss the question: *Resolved:* That all the discoveries of electricity are not worth as much to the world as the work of practical breeders of plants and animals.
2. Make a survey of all the industries in your locality and classify them according to the following headings: not dependent on the sun, somewhat dependent upon the sun; very dependent upon the sun. Make the results of your survey into chart or graph form and post on the bulletin board.
3. Take a series of photos of some one of the industries in your locality and exhibit at a club meeting.
4. Make a survey of the parasites on the plants in your locality and show what is being done to fight them.

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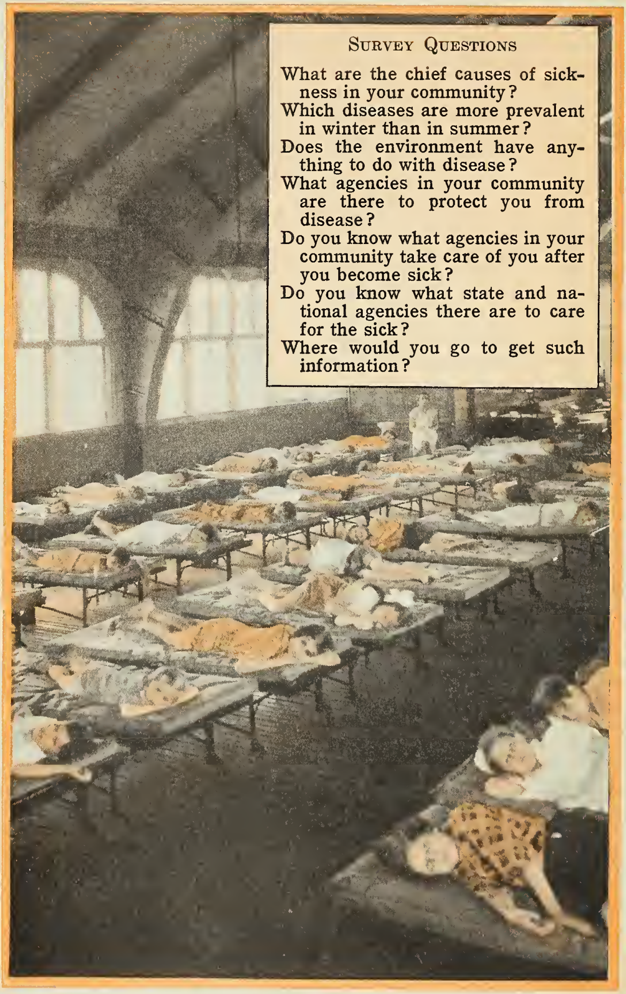


SURVEY QUESTIONS

- What are the chief causes of sickness in your community?
- Which diseases are more prevalent in winter than in summer?
- Does the environment have anything to do with disease?
- What agencies in your community are there to protect you from disease?
- Do you know what agencies in your community take care of you after you become sick?
- Do you know what state and national agencies there are to care for the sick?
- Where would you go to get such information?

UNIT XVI

NATIONAL PROTECTION OF HEALTH

PREVIEW

Man has been on earth a good many thousands, perhaps hundreds of thousands of years. But the era of scientific protection of health dates back little more than half a century. It was as late as the seventeenth century that an English physician gave the following remedy for fever: "Pare a patient's nails, put the parings in a little bag, tie the bag around the neck of a live eel and then put the eel in a tub of water." The early physician was a barber and was in addition frequently the keeper of a bath. He bled people for various troubles, often doing more harm than good. It is said that the death of George Washington was hastened by bleeding. It was not until after the beginning of the 19th century that modern medicine began. In 1796 Jenner showed the value of cowpox vaccine in fighting smallpox. But it was over 50 years later that Pasteur was making his discoveries as to the bacterial nature of disease and its control. In 1882 the German, Koch, discovered the germ that caused tuberculosis; shortly after this Laveran discovered the cause of malaria, although it was years later before Grassi and Ross found how it was carried to man. Then came the epoch-making discoveries by Major Reed's Commission in Havana which resulted in the control of yellow fever. Since that time, science and medicine have given us discovery after discovery which has resulted in the lengthening of the life span from 33 years as it was in the seventeenth century, to nearly 60 years at the present time.

People today, however, are not all willing to listen to the scientist and the doctor. We are all more or less careless when it comes to our health. We know some particular food does not agree with us, but we eat it because we want to, and we are made ill. I know that I take cold when I get my feet wet, but I hate to wear rubbers — so I take cold. Mother knows that Sally is not well and that she shows symptoms of coming down with some catching disease, but she allows other children to play with her just the same. People even carry horse chestnuts in their pockets to guard against rheumatism or cross their fingers to ward off disease. We may not believe in the medicine man of the savage, but we still as a nation consume more patent medicines than any other civilized people. Man today, although not quite as superstitious as his ancestors, is still far from being scientific in his attitudes about health.

Galloway

The public likes to be fooled. Have you ever seen anything like this?

For this reason, if for no other, it looks as if the state and national governments must come to play an increasingly large part in the control of disease. One public health official has well said that public health is purchasable. It is, but we have to pay for it. It is estimated that the public pay almost \$3 a year per capita for patent medicine but less than 60¢ per capita a year for health work undertaken by local, state, and federal authorities. We spend less than half the amount on our public health work in this country than we do for chewing gum. We spend 13 times as much for candy a year as we do for public health, or 30 times as much for tobacco as we do for the work of public agencies which are trying to keep us well.

There are a good many reasons why the health of the individual should be considered the concern of the nation. The prosperity of our nation depends upon the health of the individuals which make it up. We spend large sums of money in the improvement of plants and animals for the farmer, in caring for the feeble-minded, or the already sick. Why should we not be prepared to spend still more money to keep people well? We have still many ignorant people who do not know how to keep well. We have many others who for economic reasons think they cannot afford to go to a physician. We still have selfish people who do not consider the rights of others. All of these ought to be taken care of by the state. One large insurance company for many years has found it profitable to carry on a campaign of health education among their policyholders and figure that they have saved over $11,000,000 a year in death claims just because people took better care of themselves. This work of education is one of the biggest factors in making people health-minded. You have been given information along these lines. Why not do your part in setting an example of sane living to others who are not as fortunate as you?

Before you begin the study of this unit, you will want to recall some of the generalizations that have been reached as a result of the study of some of the previous units in your science course. These are the following, add others if you can:

1. Bacteria cause infectious or communicable diseases.
2. The symptoms of diseases are due to toxins or poisons given off by bacteria.
3. Most infectious diseases are spread by the droplet method of infection.
4. Quarantine is a protection against spread of infectious diseases.
5. Certain insects carry disease.
6. Immunity is either natural or acquired.
7. Acquired immunity is either active or passive.
8. Active immunity is obtained when the body does active work in warding off disease. The body manufactures its own antibodies.
9. In passive immunity, antitoxins are given which provide the protection.

If you do not understand all of these principles, go back to *Science in Our Social Life* and refresh your mind on the facts which underlie these generalizations.

PROBLEM I. WHAT IS THE COST OF DISEASE TO THIS COUNTRY?

Why Do People Die before They Are Old? In Roman times the life expectancy was about 30 years, but today it is about 60 years. Seventy years of age doesn't seem aged to some of us. There have been many men of note who have done their best work after they were 70 — Galileo, Michelangelo, and Von Hindenburg are typical examples. But the old age of Biblical time was not often reached, according to what little information we have. We have seen that the span of life has been gradually increasing through the centuries, although it is not the same today in all parts of the world. In India and China, for example, the life expectancy is much less than in the United States. Why this difference? Evidently environment has something to do with the death rate. India and China are swept by epidemics and famine; their systems of sanitation are less effective than ours; they have fewer doctors and dentists per capita. All these and other factors are reasons for the difference. In our own country there may be a large difference in the amount of sickness and death, depending upon the state. Minnesota, Montana, Nebraska, Kansas, Oregon, Washington, and Wisconsin, for example, stand well below the average of deaths for the country; while Delaware, Maryland, Virginia, South Carolina, and Louisiana stand out as states which have more deaths than the average. The reasons for the difference here may be environment, more likely it is caused by different populations, because Negroes and some foreign stocks have more illness than pure American stocks. Differences in working conditions and poverty may also play a part. Especially does infant mortality play a part, the death rates for Negro babies being much higher than for white children.

What Diseases Kill the Most People? If you will study the tables issued by the Public Health Department of the United States, you will find that certain diseases take a much greater toll than others. For example, in the last 20 years the death rate from typhoid, measles, scarlet fever, whooping cough, diphtheria, tuberculosis, meningitis, bronchitis, and pneumonia have been steadily decreasing. But on the other hand, the death rates from certain diseases such as heart diseases and cancer and one or two others have been increasing. The cause of cancer has not as yet been found, and consequently we are baffled in our attempts to overcome it. Heart diseases apparently are at least partly caused by the more rapid rate of living of this generation. The so-called diseases of old age are, of course, responsible for many deaths. Tuberculosis, which was once our greatest foe, still takes many people at the age of their greatest economic usefulness. Still other diseases are those of childhood. Of these, diphtheria used to be the most serious but it is now practically conquered in most parts of the country.

What Diseases Cause the Most Illness? A good many of the studies made show colds and influenza as heading the list. Colds keep more children home from school than any other cause, although measles and mumps are next on the list. In a survey of 18,000 factory workers by the United States Department of Public Health Service, colds ranked first, with influenza and pneumonia ranking second, while other surveys show similar figures. Diseases vary with the season, colds and other diseases of the respiratory tract being much more prevalent in winter than in summer. It is evident from these figures that the common cold becomes the property of a good many people. Susceptibility to disease also differs greatly with age, and the so-called "children's diseases," measles, mumps, chicken pox, whooping cough, and scarlet fever, are examples, while people beyond middle age suffer most from rheumatism, heart trouble, cancer, disease of the kidney, and tuberculosis.

What Is the Cost of Disease to This Country? There have been a good many estimates of the cost to this country of disease and needless death. It was in the World War that we first awoke to the fact that as a nation we were not as fit as we thought we were. In an examination of about 35,000,000 men drafted for service, it was found that 42 per cent were defective and 21 per cent were rejected as unfit for service. Surveys of school children have shown that between 50 per cent and 75 per cent had minor defects as bad teeth, defective eyes or ears, malnutrition and other disorders which, if left uncorrected, would make serious difficulties in later life. Several estimates have been made of the actual cost to society of preventable illness, but they are of course mere guesses. But suppose that in this country there are 40,000,000 wage earners who are disabled for 8 days during the year and that they earn only $2 a day, then the loss in wages would be about $1,000,000,000. If we add to this figure the cost of medicine, nurses, hospital costs, the cost in inefficiency of workers who are unable to do their best work because of illness, and finally the cost of the yearly deaths of some 1,400,000 people who died before their time — the staggering total of economic wastage is estimated at nearly $5,000,000,000 a year. Of this waste a very large part could be prevented if people could be better taken care of and persuaded to live more hygienically.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

$1,000,000,000
37 per cent
inefficient
lost
draft
science
Caesars

smallpox
colds
economic
42 per cent
efficient
respiratory
twice

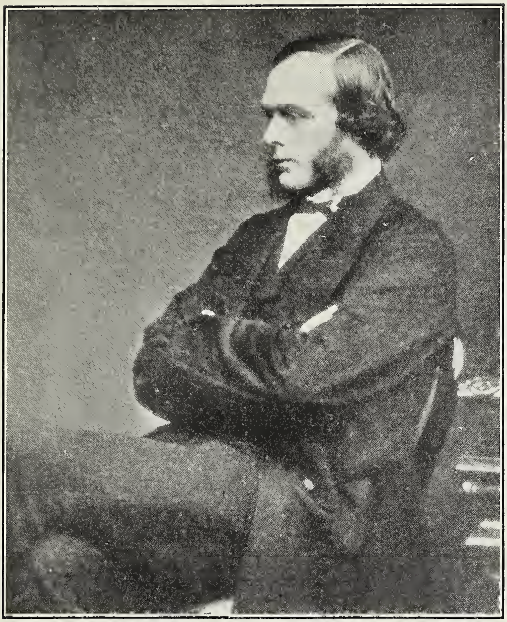
$5,000,000,000
more
improvement
fewer
doctors
found
cancer

$500,000,000
27 per cent
lives
pneumonia
heart
once

The life expectancy today is almost (1)____ that of a man during the time of the (2)____. Most of the (3)____ has come in recent times due to the advances in (4)____. Certain diseases such as (5)____ diseases and (6)____ are killing (7)____ people today than ever before. The diseases which cause the most illness are (8)____, influenza, and (9)____, all diseases of the (10)____ organs. The cost of diseases can only be guessed. At the time of the World War (11)____ of the men in the selective (12)____ were found defective. Since then a study of the cost of diseases indicates that when we take account of the cost of (13)____, hospitals, days of work (14)____, inefficient work due to disease and (15)____ needlessly lost, that the total (16)____ loss is nearly five billion dollars a year.

PROBLEM TEST

Give at least three good reasons why you would expect the death rate per 100,000 inhabitants to be higher in Louisiana than it is in Oregon. Consult outside sources of information before you give your answers.



JOSEPH LISTER, 1827-1912.

JOSEPH LISTER was the son of a famous optician of his day. He went to a Quaker school and later graduated from the University College in London. He was trained in medicine under men who were leaders in their fields, and went into surgery. At this time an appalling number of patients died following surgical operations and Lister began an investigation of the reason for this. About this time the discoveries of Louis Pasteur had shown the relation of germs to disease, and had also proven that some of these germs were in the air and that they did not arise by spontaneous generation. Basing his experiments on these facts, Lister made the first use of an antiseptic in dressing wounds after operations. He first used strong carbolic acid, which, in spite of the burns it gave, was so helpful that it formed the basis of antiseptic surgery for a long time. Later, Lister introduced a carbolic spray into the operating room, on the theory that this would kill the germs in the air.

Lister's work forms the basis of our modern antiseptic surgery.

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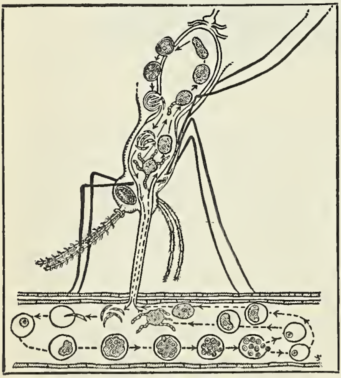
PROBLEM II. WHAT ARE SOME OF THE RECENT NOTABLE ACHIEVEMENTS OF SCIENCE?

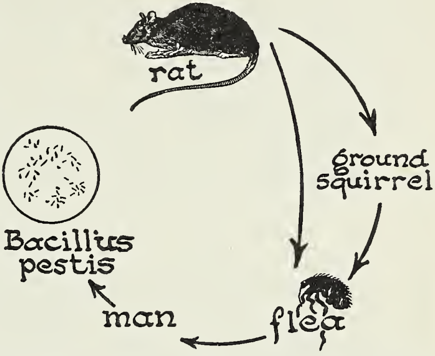
What Changes Have Recently Been Brought About by Science? Modern science applied to the betterment of man's health is very recent. It may be said to have come with the work of Jenner in smallpox and the discovery that bacteria caused disease by Pasteur and Koch only sixty years ago. Since that time many other discoveries have been made that directly influence the health and betterment of mankind. Many new discoveries have been made in preventive medicine by the use of serums and antitoxins, all following the work of Pasteur, Koch, Von Behring, and others. Lister in 1867 began the modern use of antiseptics in surgery. Then came the first use of anesthetics, giving thousands relief from the suffering of operations. The writers of this book have seen in their lifetime the conquest of typhoid fever, yellow fever, malaria, and bubonic plague. The discovery of food vitamins has resulted in the better health of millions of children, while the newer knowledge about the endocrine glands has also played an important part in the understanding of certain diseases. See pages 402–431, *Science in Our Social Life*, to refresh your memory about diseases and health.



The diagram shows the malarial mosquito with malarial parasites in its body. The lower part of the figure shows how the parasite attacks the red blood corpuscle of man, and the resulting changes that take place inside the corpuscles. How does the parasite get from man to the mosquito? From the mosquito to man?

What We Have Recently Learned about Insects and Disease. We have already discussed how malaria and yellow fever are transmitted to man by mosquitoes. We also know the *cause* of malaria: it is a tiny protozoan, which gets into the blood through the bite of a female *Anopheles* mosquito, and goes into the red corpuscles, literally destroying them by the millions. The organism that causes yellow fever is not yet definitely known; probably there are several kinds of yellow fever, each caused by a different parasite. We have also read of the harm done by flies in carrying disease germs; typhoid fever, dysentery, and other diseases that may be carried through foods, being examples of diseases thus carried.

The Relation of Fleas to the Bubonic Plague. Bubonic plague, the Black Death of the ancients, was estimated in the fourteenth century to have killed 25,000,000 persons in Europe alone. In India between 1896 and 1917 it swept off over 10,000,000 people. It is now prevalent in Asia, and as we know from the experience of San Francisco in 1907, its introduction into this country is always possible. Rats and ground squirrels become infected with the disease, and fleas which live upon them get the infection. When a rat dies of plague, fleas leave this rat and go to another rat, or possibly to a human being. Then if the flea bites a human being, he may be inoculated with the plague. On the outbreak of plague in San Francisco, the Public Health Service of the United States was called in to take charge, as the situation seemed very serious. Over 1,000,000 rats were killed, thus partially removing one means of infection, and by means of careful and rapid work the situation was soon under control with only 78 deaths, as against millions of deaths in Asia. This showed what scientific control could do.



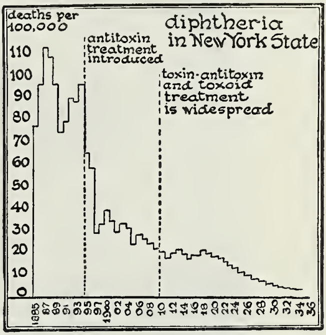
Explain from the diagram, how the bubonic plague is carried?

The Relation of Lice to Disease. During the World War many problems of disease transmission were solved and conquered, thanks to the splendid work of the sanitary and medical officers of the allied armies. Two serious diseases were typhus and trench fever. Both diseases are caused by somewhat similar organisms and are transferred by the body louse or "cootie," as the soldiers called it. After the part played by the louse was discovered, disinfecting plants were established for men coming from the trenches, their clothing was carefully disinfected as well, and the danger was greatly reduced. Typhus fever has long been known as a disease associated with poverty and overcrowding, so the part played by lice is now easily seen.

Other Diseases Carried by Insects. The part played by the mosquito caused scientists to suspect other insects of carrying disease, and they began to investigate many tropical diseases. It was not long before many new diseases were added to the list. The most dreaded of these is "sleeping sickness." This is caused by a tiny one-celled animal called a *trypanosome* which is carried by the *tsetse fly*. This fly we find not more than 150 feet from the banks of streams or lakes, so that it is quite possible that the disease may be successfully fought by keeping away from bodies of water where these flies live. *Elephantiasis*, another tropical disease, is caused by a worm-like parasite called *filaria* and is carried by mosquitoes and insects. Dengue or "break-bone fever," as it is called, is an intensely painful disease caused by a one-celled animal, and carried by the *culex* mosquito. Other diseases carried by insects are "malta fever," "kala-azar," and probably leprosy.

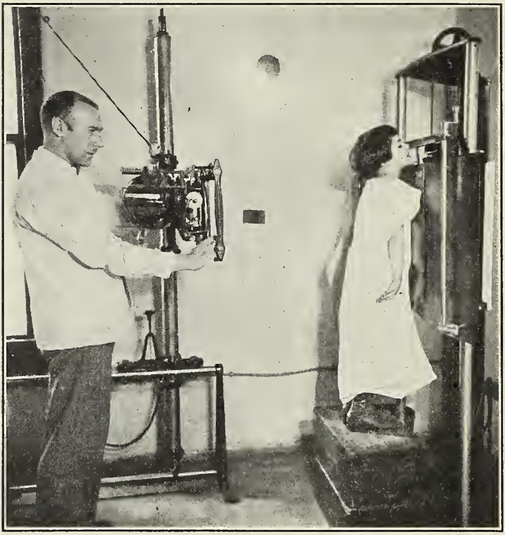
Recent Discoveries about Human Carriers. Another recent and very important discovery of medical science is that many diseases are spread by human carriers. Such people have the disease perhaps so lightly that it is not recognized and this makes the human carrier still more of a danger. We have already spoken of Typhoid Mary as a carrier of typhoid (see pages 372–377, *Science in Our Social Life*). It is estimated about 3 per cent of the persons who have typhoid are carriers, who may hold active germs in their body for months or even years. Cholera, scarlet fever, diphtheria, cerebrospinal meningitis, pneumonia, infantile paralysis, and probably other diseases are spread by human carriers. Of course, all people with active disease germs in their bodies, such as those of tuberculosis, colds, etc., are able to pass on the disease to others and thus are sources of danger. Science has told us to quarantine people who are ill but it is almost impossible to detect a disease carrier until he has infected enough people to cause an outbreak of the disease he carried. Then the harm is done. We have no adequate laws dealing with human carriers.

Recent Discoveries in Immunology. We have learned that in certain germ diseases we can successfully combat the disease by making the person immune to the disease, that is, making him build up a resistance to it. This immunity to a given disease, as we have learned, is given either by active or passive methods. In cases of active immunity, a *vaccine* is given, made either from dead germs, as in typhoid, or from weakened organisms causing the disease, as in smallpox. Then the person's body manufactures antibodies to counteract the disease, hence we call it active immunity. Experimental work is constantly adding to the number of diseases fought in this way. The following is a partial list: cholera, typhoid, tetanus or lockjaw, and smallpox. The use of antitoxins to confer passive immunity is seen in the case of diphtheria and scarlet fever. The discovery of a possible cure for scarlet fever was made in 1925 by Dr. Dick and his wife. Preventive and curative serums are now being used in the following diseases, in some cases with very good results: diphtheria, scarlet fever, amoebic dysentery, measles, blood poisoning by streptococci, meningitis, and infantile paralysis.



Deaths from diphtheria in one state. What is the story this graph tells?

One of the most important recent discoveries is that of the Schick test. An Austrian named Schick discovered that if a minute amount of toxin was placed under the skin, a reddening of that area would take place if the child was susceptible to diphtheria. Such children could be given the toxin-antitoxin treatment in which a mixture of diphtheria toxin and antitoxin was given, thus preventing the child from getting the dread disease. A recent modification of this treatment is the use of *toxoid* in which the toxin is treated with chemicals which make it harmless and is then inoculated, thus giving the child immunity.



National Tuberculosis Association

Taking a chest X-ray photograph. Several of these photographs can be made in an hour, thus making it possible to use this diagnosis in a health examination of school children.

The problem of tuberculosis is still with us, and no effective serums have been discovered with which to fight it. But by means of the tuberculin test, which acts in a similar way to the Schick and Dick tests, it is possible to know whether a person has tuberculosis germs in the body. If the test is positive, showing the presence of germs, then X-ray photographs are made of the patient to see when the germs are at work. When a diagnosis[1] is made, the patient is placed in a sanitarium where the disease is usually soon cured by rest, nourishing foods, and proper care. Many sanitariums have been built, supported by the national or state governments or private charity. But our knowledge of how to prevent and treat the disease has been so much advanced in the past few years that the death rate from tuberculosis is steadily decreasing.

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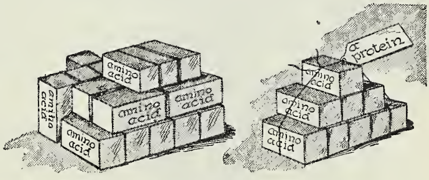
[1] Diagnosis. The act of recognizing the presence of a disease from its symptoms.

The Stamping Out of Hookworm. One of the worst enemies of man in the tropics is the parasitic hookworm. The Rockefeller Foundation, which is now engaged in combating this pest in all parts of the globe, estimated that probably 75 per cent of all the natives of southern China and over 90 per cent of all laborers in Dutch Guiana and Colombia are infected with it. Dr. W. C. Stiles, of the Bureau of Animal Industry, discovered a few years ago that the hookworm was the cause of the shiftlessness and ill health of many of the people of our southern states. Its life history was not well known then, but more recently we have learned how to combat it.

The worm gets into the body from the soil, usually through a break in the skin of the feet. Wearing shoes is one of the necessary protections against it. The young worms go through a long journey in the body, but they finally fasten themselves to the inner wall of the food tube, where they suck the blood of their hosts. They also poison the wound so that much blood escapes from it. This weakens the infected person and makes him susceptible to other diseases, particularly tuberculosis. The cure is easy, as treatment by such drugs as thymol, followed by Epsom salts, gets rid of these unwelcome visitors.

New Discoveries about Nutrition. If we sum up our knowledge here, we find that the most important things we have found deal with the value of foods containing the regulative substances we call vitamins. These vitamins, of which six have been definitely isolated, are called A, B, C, D, E, and G or PP. They are found in many different foods, but largely in fruits and green vegetables. It has been found, for example, that if vitamins A, C,

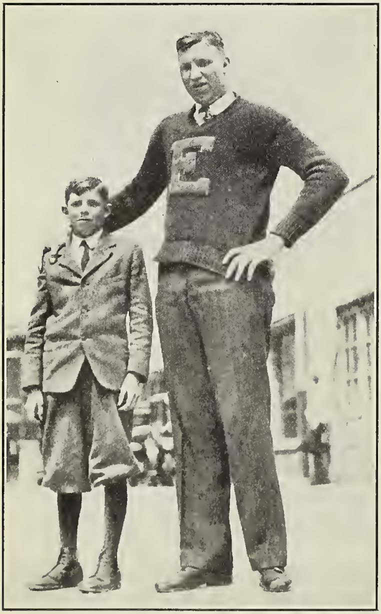


There are eighteen different amino acids. Where any number of these are bound up chemically they form a protein.

and D are supplied with small quantities of calcium and phosphorus in a diet of milk, butter, eggs, fresh fruits, and vegetables, the teeth will grow and keep in good condition. Refer to *My Own Science Problems,* pages 318–320, to recall the specific values of these regulative substances. Another discovery of great importance is that not all proteins are useful to build tissues in our bodies. Animal proteins are in general better tissue builders than plant proteins. Other recent important discoveries have to do with the importance of the mineral constituents of food and the importance of milk as a food.

New Discoveries Concerning the Endocrine Glands. Diabetes is caused by failure of the pancreas to produce an internal secretion which gets into blood and controls the amount of sugar that can be used. When the apparatus fails to work, the person cannot use sugar. A discovery by Banting in 1922 of a substance called insulin, which he isolated from the pancreas of animals, has resulted in saving thousands of lives of diabetic patients.

Much has recently been learned about the nature of the thyroid gland. One abnormal condition, goiter, or swelling of this gland, is now discovered to be due to lack of iodine in the body. This discovery came about through finding that trout in a certain hatchery developed goiter, but when they were fed on sea food the goiter disappeared. Sea food has iodine in it



International News Photo, Inc.

Two classmates of the same age. One is normal height, the other nearly seven feet tall.

and when iodine was added to the water in which they lived, the fish lost their goiter. This has been applied on a large scale in parts of our country where iodine is lacking in the water supply, with the result that most of the goiter disappeared.

Other interesting discoveries have been that the pituitary gland, located at the base of the brain, controls body size, being responsible for the dwarfs and giants we see in the circus; that the parathyroid apparently controls the amount of calcium in the blood; and that the adrenal gland has a secretion that "peps us up" when we are frightened or angry.

Some Unconquered Diseases of Mankind. In spite of all that science has done, there are a few diseases that are slowly but steadily increasing. For example, more people die from cancer today than a few years ago, in spite of all the work that scientists are doing on this disease. This may be because we are better able to recognize cancer than we used to. The deaths from heart trouble are slowly rising, probably because of the rapid pace life sets for us at present. Mental diseases, while they may not be increasing, are costing the country a very large sum in institutional care. The problems of the feeble-minded, the alcoholic, and the drug addict are all part of a program of social reform which the readers of this book must be strong enough to carry out in the next generation.

SELF-TESTING EXERCISE

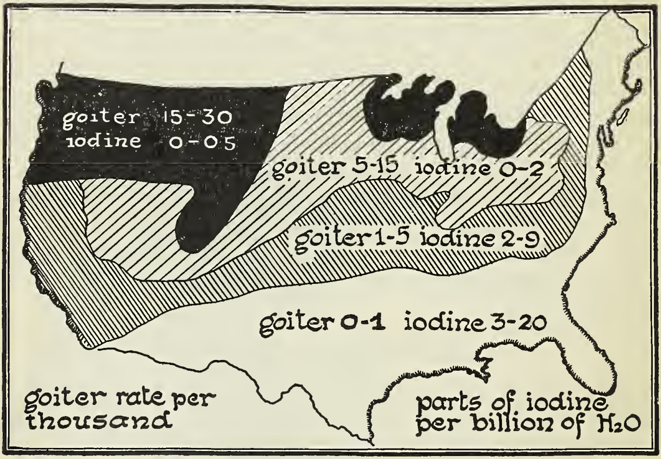
Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

yellow
flies
uncontrol
lice
increasing
immunity
controlled
vitamins
fleas
ants
nutrition
bees
decreasing
vaccines
carriers
malaria
mosquitoes
malnutrition
endocrine
less
serums
drugs

Some of the recent conquests of medical science have resulted in the control of (1)____ and (2)____ fever by finding the carriers of the disease in the form of two different (3)____. Other insects that carry diseases are (4)____, (5)____, and (6)____. Human (7)____ of disease are very important because it is difficult to (8)____ them. Great advances have been made in the use of (9)____ and antitoxins and (10)____ to give (11)____ against different diseases. The fight against tuberculosis is gaining ground and the death rate from it is (12)____. Much new knowledge has been gained about the (13)____ glands, which control our health, and to an extent, our personality. Newer knowledge of (14)____ has come to give us reasons for eating or not eating certain foods because of the (15)____ contained.

PROBLEM TEST

What proof have we from the statistics shown in this figure that goiter has any connection with iodine? What would you do if you lived in the so-called "goiter belt" of the United States?


goiter 15-30
iodine 0-0.5
goiter 5-15 iodine 0-2
goiter 1-5 iodine 2-9
goiter 0-1 iodine 3-20
goiter rate per thousand
parts of iodine per billion of H_2O

PROBLEM III. WHAT AGENCIES CONSERVE HEALTH?

The Individual an Agent. No one will be well and healthy unless he wants to be so. This book may be full of warnings and suggestions, but it is the actions of the boys and girls who read the suggestions that count either for or against health in a community. We have seen that the factors which make for health are everywhere the same. If a normal individual lives in an environment which supplies good air and plenty of it, pure water and food, sunlight in abundance, and proper clothing and shelter, he should keep in good health. But we know that this is not always the case. The normal individual is careless, he abuses himself by reading in a bad light, drinking impure water, eating food that does not agree with him, or exposing himself to the germs of disease. His environment may be the best possible, but his health depends almost entirely on the way he cares for himself.

Improvement in Environment a Factor in Better Living. People all over the civilized world have a much better chance today to enjoy life than those of a few years ago. When the writers of this book were boys, the slum conditions in many of our cities were unspeakably bad. The tenements were dirty and ill kept, with rooms having inadequate ventilation. The streets were seldom washed and piles of refuse and garbage were common. Child labor was permitted almost everywhere and amounted to virtual slavery in many places. Children worked long hours under conditions which were most insanitary.

Today improvement of environment is very definite along several lines. Housing conditions are better in all countries; streets are properly cleaned; refuse frequently collected; parks have been made where slums formerly existed; foods are protected by law; laws have been made which prevent such unfair

Courtesy National Tuberculosis Ass'n

Such living conditions as are illustrated in the room above are one of the causes of poor health.

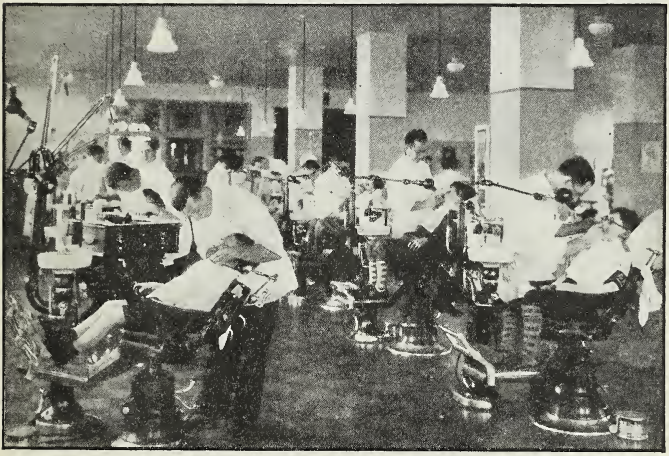
treatment of children; the working conditions in factories are much better than formerly; the hours of work are shortened so that the workman has opportunity for recreation; and scientific knowledge on the care of babies is available to all people.

Restroom in the University High School, Oakland, Calif. This is a school that has a complete health program.

What Education Does. We have seen that good heredity plays a most important part in our life, but if we are to be successful, we must also have an education and use it. The pages written in this text, if *used*, will help us make our environment a safer and better place to live in. Education has gradually raised the intelligence of the human race, but everyone has had to learn many things for himself or herself. Schools will always be a most important factor in our environment, and to make progress, we must learn to take advantage of what we can get from them. Practically every school today has a well-planned health program in which all departments of the school are helping. Health examinations are made by the school physicians at the beginning of the year, and if defects are found the school nurse follows these up. Corrective work is given in the physical culture department, as well as organized play and games. Dental, lung, heart, and mental hygiene clinics are usually established by the city board of health, and hygiene is taught in a practical way through the establishment of good habits. Schools educate us to be intelligent citizens. As such we should, among other things, co-operate with every health measure, and in that way do our share toward making public education count in a practical way.

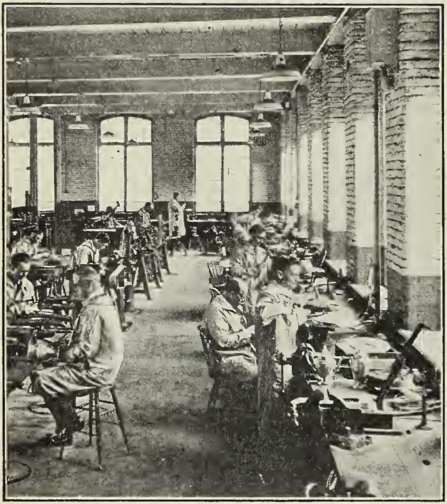
The Doctor Should Reduce Illness. The losses from sickness in the United States are estimated at two billion two hundred and fifty million dollars a year. This staggering sum, which includes nurses' and doctors' bills, loss of wages or productive work, and losses in the family, ought to be much reduced. How are we going about to reduce it? First, we must consult good physicians regularly and take their advice on how to keep well. It is as important to be examined once a year by a good physician as it is to have one's teeth cleaned by a dentist every six months.

At present, the standards of the doctors in this country have been raised to a very high degree so that all who want to become



A dental clinic. Here you may have your teeth examined and cleaned. If there is anything wrong with your teeth, a competent dentist will give you expert treatment. Find out if there is a dental clinic in your neighborhood. You should have your teeth examined at least every six months.

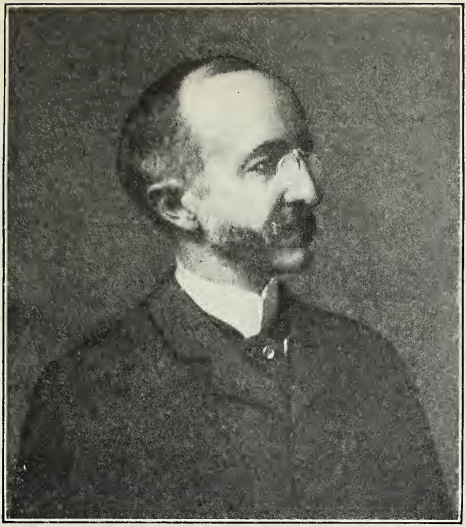
physicians must be well trained and have considerable hospital experience before they begin to practice. Unfortunately, there are many so-called doctors who have never had real training, and who profess to be what they are not. Some of us do not have sufficient knowledge to recognize the difference between a well-trained physician and a "faker." We can always get this information by going to any reliable source, such as the board of health in our own town.



National Jewelers' Publicity Ass'n

Efficient work is done in clean, sanitary factories where there is plenty of light.

Industries and Health. Most industries have discovered that it pays to take the best possible care of their employees. We have seen in a previous unit how the industrial hazards of poisoning, dust, injuries from machines, and other dangers have been cut down by means of proper ventilation and lighting, by guards around cutting machines, and by reducing the danger from fatigue by rest periods. In some industries a very complete health service has been worked out. Hot lunches are served to the employees, short periods of relaxation are given in the morning and afternoon, rest rooms, gymnasiums, and classes in physical education are provided. The employee is given a health examination when beginning work, is given free dental care, and if ill, a visiting nurse follows up the case. Many large organizations have worked out very complete health programs. Such programs include (1) health and medical examinations; (2) sanitation and safety



EDWARD LIVINGSTON TRUDEAU, 1848-1915.

TRUDEAU was born in New York City. He came from a medical family and although as a young man he thought of going into the navy, the illness and later death of his older brother from tuberculosis caused him to give up this plan. He became a physician and was happily married, when it was found that he also had tuberculosis. In those days, a person who had tuberculosis felt that it was a death sentence and Trudeau, who loved the woods, went to the Adirondacks to die. But living an outdoor life, he soon began to get better and eventually recovered. This showed him the value of the rest and fresh air cure for tuberculosis. He collected funds and established a small sanitarium at Saranac Lake, in a sheltered spot where he had cured his own trouble. From small beginnings this became a beautiful group of 36 buildings, housing hundreds of patients.

In addition to the sanitarium, Trudeau organized a laboratory where he performed many outstanding experiments which threw light on the treatment of tuberculosis. His work gave the foundation for our modern treatment of tuberculosis and is directly responsible for our control of this disease. He wrote many articles on the subject of tuberculosis in medical publications.

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engineering; (3) recreation; (4) housing; (5) visiting nurse service, and (6) care of injured.

Lounging and restrooms for the employees are considered a part of the essential equipment of large industrial plants.

Other Private Agencies. Besides these ways of taking care of people, we have very many private agencies at work. Everyone knows the way the American Red Cross helps out with money and supplies in case of any large catastrophe. The National Tuberculosis Association is constantly fighting tuberculosis by building sanitariums, working out plans for preventing people from having tuberculosis, and aiding those who have the disease. The American Child Health Association is doing much to improve the health of school children. The Commonwealth Fund, the American Child Health Association, and many other private agencies are doing splendid health work. The best-known private agency in public health work is the Rockefeller Foundation. The work of this board has become largely that of a research institution; but it has made the health of the world its goal and now all over the world we find established hospitals, sanitariums, and what is most important, research men fighting such diseases as bubonic plague, hookworm disease, tuberculosis, and yellow fever. The last disease has been almost brought under control, largely through the work of this foundation.

Public Health Agencies. We have already said that cities have boards of health. Some of the larger cities have a very complete organization, as can be seen from the accompanying diagram. Through its bureaus of communicable diseases, it distributes vaccine and antitoxin. Through its bureau of child health, it watches over the schools. By means of the public health nurses, the children in schools and people in homes who cannot afford to pay for medical care are helped. Most states also have health departments which in addition to making sanitary standards and laws also do much in preventing outbreaks of disease, and in fighting diseases when these outbreaks occur. In addition to this, the state departments of health have bureaus of vital statistics which gather and publish important records, facts on various diseases, which will enable the health workers to better fight different diseases. Finally, we have the United States Public

Galloway

Making a routine laboratory test. Perhaps some of you would be interested in becoming laboratory technicians.

Health Service, which protects the country from disease and helps keep out the diseases which are prevalent in other nations. This it does through operation of quarantine stations, the medical examination of immigrants, and the careful inspection of all vessels which come from foreign ports. It thus often prevents the outbreak of epidemics, which might be brought in from foreign countries. It has established laboratories which test and standardize all biological products such as antitoxins and serums, thus preventing any danger from this source. In addition it co-operates with state and local boards of health, has research laboratories which determine the causes of different diseases, and finally, it edits many bulletins and reports which serve to give health information, and gives to the newspapers a good deal of valuable information on health and disease.

Among other Federal agencies which help in health work are the Children's Bureau of the Department of Labor. This bureau publishes the results of many studies on child welfare and has been largely responsible for the recent changes in the working hours of children. The Division of Vital Statistics and the Census Bureau also publish much valuable information. The Division of School Hygiene of the Bureau of Education has many useful publications, some of which are doubtless used in your school. Other agencies which directly or indirectly help public health are the Bureau of Animal Industry, which deals with the disease of animals, many of which have direct bearing on the same diseases found in man; the Bureau of Entomology, which investigates insect causes of disease; and many other agencies, including the War and Navy departments, are also aiding health. But all of these agencies are worth very little without *your* individual help. Do you see why?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange them in proper numerical order. The same word may be used more than once.

undoing
medical
public
Child
disproved
health
improving
employees
control
Red
individual
smaller
boards
Cross
industrial
recreation

safety
nurse
improved
health
Rockefeller
private
employers
school
Service
educational
conditions
Health

In the end, no matter how much is done by (1)____ and (2)____ agencies in (3)____ health (4)____, the (5)____ is the deciding factor for health or disease. Environmental conditions have been much (6)____ in recent years, (7)____ institutions have excellent health programs in which all members of the (8)____ take part, and industries are doing more for (9)____ than ever before. Very complete programs include (10)____ examinations, visiting (11)____, rest and (12)____, and (13)____ engineering. These are found in practically all the large (14)____ organizations. In addition, we have numerous (15)____ agencies such as the American (16)____ (17)____, the American (18)____ (19)____ Association, the (20)____ Foundation, and many others which are doing fine health work. Public agencies, such as the city and state (21)____ of (22)____ and the United States (23)____ Health (24)____, also are very active in securing proper health (25)____ in the country as a whole.

PROBLEM TEST

You find in an ignorant foreign family a child who has a bad cough. You think it is a case of tuberculosis. What should you do about it? Select the best answer from the list which follows and then match with it, from the reasons given below, the one that you think best fits the case.

Answers

1. Do nothing.
2. Speak to the parents of the child.
3. Report the case to the visiting nurse.
4. Report the case to the board of health.
5. Tell the child what you think his trouble is.

Reasons

1. The parents are the natural people to speak to about their own children.
2. It may be only a case of whooping cough.
3. The child speaks English and goes to school. He will probably tell his parents what you said and they will take care of the matter.
4. She will go to the house and get a physician who will make the necessary examination.
5. They would send the visiting nurse there anyway.
6. The board of health handles all cases of contagious disease.
7. The board of health is not always very active.

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THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. Among the generalizations that can be drawn from the above unit are the following:

1. Much unnecessary suffering is caused by controllable diseases.
2. About a million and a half people die annually in this country before they should, from preventable diseases.
3. There is a yearly economic wastage estimated at from $2,500,000,000 to $5,000,000,000.
4. Most scientific discoveries which lengthen the life span are recent.
5. Discoveries with reference to carriers of disease are very important.
6. Our knowledge of vitamins is very recent.
7. Our knowledge about the endocrine glands is also recent.
8. Many public and private agencies help to conserve health.
9. Public and private health is not possible without co-operation on the part of individuals.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

In a vertical column under the heading CORRECT, *write numbers of all statements you believe are true. In another column under* INCORRECT, *write numbers of untrue statements. Your grade = right answers* × 2½.

I. **Life expectancy in the last 20 centuries has:** (1) tripled; (2) been about the same; (3) doubled; (4) become five times as great.

II. **Among the healthful states are:** (5) South Carolina; (6) Montana; (7) Maryland; (8) Oregon.

III. **The annual loss from disease and death in this country is estimated to be:** (9) $1,000,000,000; (10) $5,000,000,000; (11) $500,000,000; (12) $500,000,000,000.

IV. **Some of the outstanding achievements of the past 20 years in medicine have been:** (13) the use of antiseptics in surgery; (14) the discovery of the vitamins; (15) the first use of vaccination against smallpox; (16) the discovery of the organism that causes yellow fever.

V. **The following insects are known to carry diseases:** (17) fleas; (18) all mosquitoes; (19) butterflies; (20) lice.

VI. **Human carriers are important because:** (21) they are often not known; (22) they are hard to control; (23) we have no adequate laws to protect us from them; (24) they may carry typhoid, scarlet fever, diphtheria, meningitis, cholera, pneumonia, infantile paralysis, and probably other diseases.

VII. **Immunity:** (25) may be conferred by having a disease; (26) is active or passive, depending on whether the body does the work of making antibodies; (27) cannot be given in diphtheria; (28) is given by the Dick or Schick tests.

VIII. **Recent discoveries in nutrition show:** (29) that a man with an intestine longer than his stomach will die young; (30) that the vitamins are regulative substances necessary for health; (31) that milk is a poor food; (32) that all proteins are of equal value for tissue-building.

IX. **The chief reason why people are ill is because:** (33) they do not go to the doctor as soon as they feel sick; (34) industrial poisons affect so many; (35) people are careless in obeying the "rules of the game" of life; (36) people become fatigued and then get sick.

X. **Important agencies working for good health are:** (37) the American Red Cross; (38) Rockefeller Foundation; (39) the Children's Bureau of the Department of Labor; (40) the United States Public Health Service.

PRACTICAL PROBLEMS

1. Can you make out a food dietary that will prevent rickets?

2. Can you plan an experiment other than those given in your text, that proves milk is a good food?

3. Find out how many members of the class are immune to diphtheria; to scarlet fever. How would you find this out?

4. Find out from your local board of health how many children have had diphtheria and how many died from it in your community in the last five years. Then estimate the money loss to the community, if the child's worth is estimated at $3000 and the medical care of the sick child is worth $100.

5. Try the above estimate with other communicable diseases mentioned on page 539.

6. Is your city making the best use of its allotment of taxes for health work? Justify your answer.

7. What organized efforts have there been to have all children in the community Schick tested and the susceptible ones given toxin-antitoxin or toxoid treatment? How could the community do this?

8. Why are gymnasiums and playgrounds helpful in industrial plants?

SCIENCE FOR LEISURE TIME

1. Make a visit to some large industrial plant and report to the class on what safeguards are used for protection against accident and fatigue.

2. Make a list of all the journals and publications you know that aim to conserve public health.

3. What agencies mentioned in Problem III are at work in your community? What is the field of each agency? Are there others not mentioned? If so, what do they do?

4. Write a short report on "The Most Important Agencies in the Conservation of Human Life."

5. Compare the treatment of a sick person at home and in a hospital. Make a visit to the local hospital to see just what is done.

6. Make a chart showing the relation of the various departments in your city board of health to each other and to the citizens of the community. Ask your teacher to criticize it and if it is good enough, exhibit it.

7. Make a collection of pictures to show the development of a modern hospital. Go to your local board of health for suggestions. Exhibit your collection.

8. If you are a stamp collector, see how many Red Cross or charity stamps you can find in your stamp catalogue. What good were such issues?

9. Make a list of all the unsafe living conditions you find in your neighborhood. How would you go to work to better them?

10. Make a collection of pictures on disease prevention.

11. Make an original poster on some phase of community hygiene and exhibit it on the bulletin board.

SCIENCE CLUB ACTIVITIES

1. Make a trip to the Health Department. Allot a report on each activity of the department to different members of the club and have a meeting devoted to the reports.

2. Put in a school assembly devoted to the health work of your city or the state and get some member of the department to give a short assembly talk. Be sure that your speaker knows how to talk to young people so that the interest of the meeting will be kept.

3. Have the club make a survey of some parts of your community to show the ways in which members of the community do and do not co-operate with the city health department.

4. Make a survey of your class to see how many cases of contagious diseases there have been among members in the past year. Find out in each case how the disease was contracted, try to decide whether it

could have been prevented, find out how many days of school absence there were, and then estimate the cost to the community of the total days of absence. Your principal will furnish you the loss per pupil per day.

5. Have a debate on some of the following topics:

Resolved: That the mountains offer greater advantages for healthful recreation and for recuperation than the seashore.

Resolved: That the government should cease to exercise control over foods and drugs sent from one state to another, but leave to each state the entire control of foods and drugs within that state.

Resolved: That heredity is more important than environment.

LIBRARY RESEARCH READING AND REPORTS

1. Read Paul De Kruif's *Men Against Death, Hunger Fighters,* or *Microbe Hunters.*
2. Read the life of Edward Trudeau.
3. Report on the work of the United States Public Health Service.
4. Report on the work of the Rockefeller Foundation.
5. Report on the protection given employees against industrial hazards.

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GLOSSARY

The diacritical marks are those used in Webster's New International Dictionary.

abalone (ăb′ȧ-lō′nē): A food mollusk having a shell lined with mother of pearl.

acetylene (ȧ-sĕt′ĭ-lēn): A colorless combustible gas.

adaptation (ăd′ap-ta′shŭn): Modification of a plant or animal fitting it more perfectly to live in its environment.

adjustable (ă-jŭst′i-b'l): Capable of being regulated.

adulteration (ȧ-dŭl′tẽr-ā′shŭn): The state of being made of a lower grade by the addition of a foreign or cheaper substance.

Aëdes (ā-ē′dez): Mosquito that carries yellow fever.

aileron (ā′lẽr-on): A hinged movable surface of an airplane to enable pilot to roll machine on its longitudinal axis.

alfalfa (ăl-făl′fȧ): A forage plant.

alimentary canal (ăl′ĭ-men-tȧ-rĭ): Food tube.

alloy (ă-loi′): A substance formed by melting two or more metals together.

ampere (ăm′pēr): Unit of electric current.

amphibian (ăm-fĭb′ĭ-ăn): An animal that spends part of its life in the water and part on land, as frogs and toads.

amplifier (ăm′plĭ-fī′ẽr): A device to strengthen electric impulses.

anemometer (ăn′ē-mŏm′ē-tẽr): An instrument for measuring the velocity of the wind.

aneroid (ăn′ẽr-oid): A kind of barometer using a metal box from which air has been removed. It uses no liquid.

Anopheles (ȧ-nŏf′ĕ-lēz): A genus of mosquitoes whose bite is the usual means of infecting human beings with malaria.

antibodies (ăn′tĭ-bŏd′ĭz): Substances in the blood which fight harmful bacteria or toxins.

anticyclone (ăn′tĭ-sī′klōn): Our fair weather area of high barometric pressure.

antiseptic (ăn′tĭ-sĕp′tĕk): A substance that prevents the growth of harmful microorganisms.

antitoxin (ăn′tĭ-tŏk′sĭn): A substance produced in the body of an animal and used to overcome the effects of disease-producing bacteria.

Appert: He discovered method of preserving food by sterilization and sealing in closed jars.

aragonite (ȧ′răg-ō-nīt): A mineral composed of calcium carbonate.

Arkwright (ärk′rīt): Inventor of the spinning jenny.

armature (är′mȧ-tūr): A piece of soft iron to take the lines of force across the poles of a magnet; a fixed or rotating electromagnet in electrical machines.

artery (är′tẽr-ĭ): One of the large tubes which carry blood from the heart to various parts of the body.

atomizer (ăt′ŭm-īz′ẽr): An instrument to change a liquid to a fine spray.

audio (ô′dĭ-ō): Relating to electric current of frequencies corresponding to audible sound waves.

automatic (ô′tō-măt′ĭk): Self-acting or self-regulating.

bacteria (băk-tē′rĭ-ȧ): A certain group of microscopic plants, some of which cause diseases.

bacteriologist (băk-tē′rĭ-ŏl′ō-jĭst): An expert in the study of bacteria.

Barbados (bär-bā′dōz): A British island colony.

barograph (băr′ō-grȧf): A self-registering barometer.

bascule (băs′kūl): On the principle of the seesaw.
bifocal (bī-fō′k*ă*l): Having two foci.
binocular (bĭn-ŏk′ū-lẽr): Employing both eyes at once.
Boise (boi′sĭ): A city in Idaho.
buoyancy (bo͞o′y*ă*n-sĭ): Upward force exerted upon an immersed or floating body by a liquid or a gas.

caisson (kā′s*ŭ*n): A large air chamber in which men work under water in compressed air.
calorie (kăl′ō-rĭ): The amount of heat necessary to warm 1 kilogram of water 1° C. or about 4 pounds of water 1° F.
calorimeter (kăl′ō-rĭm′ē-tẽr): Apparatus for measuring amount of heat in foods.
calyx (kā′lĭks): The outer floral leaves of a flower. All the sepals taken together.
capillaries (kăp′*ĭ*-lẽr′iz): Fine, hair-like tubes; the very small blood vessels through which the blood flows from the arteries to the veins.
carbohydrate (kär′bō-hī′drāt): A group of compounds containing carbon, hydrogen, and oxygen, as sugar and starch.
carburetor (kär′bū-rĕt′ẽr): A device on an engine which aids the mingling of air with gasoline vapor; a structure in which oil is changed to vapor in the manufacture of water gas.
cell (sĕl): A small structural unit of which plants and animals are composed.
centrifugal (sĕn-trĭf′ū-g*ă*l): Flying away from the center.
chassis (shăs′ĭ): Automobile frame.
chlorophyll (klō′rō-fĭl): The green coloring matter of plants.
chloroplasts (klō′rō-plăsts): The bodies containing chlorophyll or green coloring matter.
chromosomes (krō′mō-sōms): Bodies in the nucleus which are believed to carry inheritable characteristics of plants and animals.
circulation (sûr′kū-lā′sh*ŭ*n): The process by which oxygen and blood flow to all parts of the body.
cirrus (sĭr′*ŭ*s): A white filmy cloud at great heights.
climate (klī′măt): Average weather conditions.
clinker (klĭngk′ẽr): A stony fused mass.
commutator (k*ŏ*m′ū-tā′tẽr): A device for taking current from the armature of a generator or of taking it to the armature of a direct current motor.
compression (kŏm-prĕsh′*ŭ*n): Act of reducing volume by pressure.
corolla (kō-rŏl′*a*): The inner petals of a flower.
corpuscle (kôr′pŭs′l): A minute cell in the blood or lymph.
cotyledon (kŏt′*ĭ*-lē′d*ŭ*n): The first leaf or pair of leaves developed in seed plants.
crystallization (krĭs′t*ă*l-ĭ-zā′sh*ŭ*n): Process of forming crystals.
cyclone (sī′klōn): Our regular periodic storm having a low atmospheric pressure at its center.

dehydrate (dē-hī′drāt): To deprive of water.
differential (dĭf′ẽr-ĕn′*shă*l): A type of gear in rear end of an automobile.
Diesel engine (dē′z*ĕ*l): An engine invented by Rudolf Diesel, a German inventor.
digest (dī-jĕst′): To change food into a form that the blood can absorb.
diphtheria (dif-thēr′ĭ-*a*): Infectious disease of the throat.
distillation (dĭs′t*ĭ*-lā′sh*ŭ*n): Act of driving off gas from liquids and then condensing the gas by cooling.
domestication (dō-mĕs′t*ĭ*-kā′sh*ŭ*n): Act of reducing from a wild state to a tame condition.
dominant (dŏm′*ĭ*-n*ă*nt): Opposite of recessive.

eccentric (ĕk-sĕn′trĭk): A revolving part having a different center from that of another part to which it is attached.
efficiency (ē-fĭsh′*ĕ*n-sĭ): The percentage of work put into a machine which appears as useful work accomplished.
elasticity (ē-lăs′tĭs′*ĭ*-tĭ): Ability of a strained body to regain its size or shape.
electrode (ē-lĕk′trōd): A terminal from any source of electricity.

electrolyte (ē-lĕk'trō-līt): A substance in solution in a wet cell; a compound.

electromagnet (ē-lĕk'trō-măg'nĕt): A soft iron bar surrounded by a coil of wire through which an electric current passes, making the iron a temporary magnet.

electroplate (ē-lĕk'trō-plāt'): To plate or cover with metal by electrical deposition.

environment (ĕn-vī'rŭn-mĕnt): Surrounding conditions or influences.

enzyme (ĕn'zīm): A substance which effects certain chemical changes.

Eustachian tube (ū-stā'kĭ-ăn): Passage from the ear to the pharynx.

fluorescence (flōō-ō-rĕs'ĕns): Property of a body to change some invisible rays into light rays.

frequency (frē'kwĕn-sĭ): The number of complete cycles of current produced by an alternate current generator per second.

galleon (găl'ē-ŭn): A sailing vessel of the 15th century.

generator (jĕn'ẽr-ā-tẽr): A machine for producing electricity; a dynamo.

germ (jûrm): A small plant or animal that may produce disease.

germinate (jûr'mĭ-nāt): To begin to grow, to sprout.

gland (glănd): An organ of the body which makes and gives off a fluid.

Hargreaves (här'grēvz): Inventor of the spinning jenny.

helicopter (hĕl'ĭ-kŏp'tẽr): A flying machine using horizontal propellers.

heredity (hē-rĕd'ĭ-tĭ): Transmission of physical and mental characters of parents to offspring.

Hereford (hĕr'ē-fẽrd): A breed of beef cattle.

horse power: The unit of power or rate of work equal to 33,000 foot pounds of work per minute.

hybrid (hī'brĭd): The offspring of two plants or two animals of different species.

hydraulic (hī-drô'lĭk): Pertaining to water.

hydroelectric (hī'drō-ē-lĕk'trĭk): Relating to the production of electricity by water power.

hygrometer (hī-grŏm'ē-tẽr): Instrument for measuring the degree of moisture in the air.

incubate (ĭn'kū-bāt): To maintain a temperature favorable for eggs to hatch.

induction (ĭn-dŭk'shŭn): A process of producing electricity.

infectious (ĭn-fĕk'shŭs): Catching; communicable; a germ disease.

invertebrate (ĭn-vûr'tē-brāt): An animal having no backbone or spinal column.

kilocycle (kĭl'ō-sī'k'l): A unit of frequency: equal to 1000 cycles per second.

kilowatt (kĭl'ō-wŏt'): A unit of power: equal to 1000 watts.

kinetic (kĭ-nĕt'ĭk): Of or pertaining to motion.

lava (lä'vȧ): Liquid rock from a volcano or such rock after solidification.

legume (lĕg'ūm): A plant such as the pea or bean, bearing pods.

lens (lĕnz): A piece of glass made to refract glass in a way to produce images.

"low": A low atmospheric pressure area; a cyclone.

macadam (măk-ăd'ăm): Road made of broken stone.

manganese (măng'gȧ-nēs'): A hard metallic element.

maximum (măk'sĭ-mŭm): Highest.

Mendel (mĕn'dĕl): Austrian abbot who worked out the laws of heredity.

microorganism (mī'krō-ôr'găn-ĭz'm): Any organism of microscopic size.

minimum (mĭn'ĭ-mŭm): Lowest.

modulate (mŏd'ū-lāt): To change the frequency of electrical waves.

momentum (mō-mĕn'tŭm): Force acquired by motion of a body.

mutation (mū-tā'shŭn): A sudden variation in the offspring differing from the parent in a well-marked character.

narcotic (när-kŏt'ĭk): A drug which in great doses produces stupor.

nebula (nĕb'ū-lȧ): A luminous body of gas in space.

nodules (nŏd′ūls): Thickened knots or lumps on roots of legumes.
Noguchi (nō′goo′chē′): A Japanese scientist who lost his life in experimenting with the organism that causes yellow fever.
nutrients (nū′trĭ-ĕnts): Substances which furnish food to the body.

organic (ŏr-găn′ĭk): Pertaining to living plants and animals.
oscillating (ŏs′ĭ-lāt′ĭng): Alternating in direction.
oxyacetylene (ŏk′sĭ-ȧ-sĕt′ĭ-lēn): A mixture of oxygen and acetylene.
oxyhydrogen (ŏk′sĭ-hī′drô-jĕn): A mixture of oxygen and hydrogen.

parasitic (păr′ȧ-sĭt′ĭk): Living on other organisms.
pasteurization (pȧs′tẽr-ĭ-zā′shŭn): A process for checking growth of bacteria in fluids by heating.
perennial (pẽr-ĕn′ĭ-ăl): Plants that grow more than two years.
phase (fāz): One of the views or forms presented by the moon.
Phoenician (fê-nĭsh′ăn): Inhabitant of the ancient maritime country of Phoenicia.
photoelectric cell (fō′tô-ē-lĕk′trĭk): A cell which by exposure to light generates electricity.
pictograph (pĭk′tô-grȧf): A picture expressing an idea.
pistil (pĭs′tĭl): The central structure of a flower, which contains the ovary.
piston (pĭs′tŭn): A disk made to slide back and forth in a cylinder.
plankton (plăngk′tŏn): Organisms having weak powers of locomotion, living in water.
pneumatic (nû-măt′ĭk): Worked by air pressure.
pneumonia (nû-mō′nĭ-ȧ): A disease characterized by inflammation of the lungs.
pollen (pŏl′ĕn): Fine dust grains from the anthers of flowers.
pollination (pŏl′ĭ-nā′shŭn): The transfer of pollen of one flower to the stigma of another.
potential (pô-tĕn′shăl): Having stored or latent power.
precipitation (prê-sĭp′ĭ-tā′shŭn): Act of casting down; a deposit of water from rain or snow on the earth.
protein (prō′tê-ĭn): Food material containing carbon, hydrogen, oxygen, and nitrogen.

quarantine (kwŏr′ăn-tĭn): Restrictions on a sick person or one suspected of being infected with a disease.

radiant (rā′dĭ-ănt): Given out or emitted by rays.
recessive (rê-sĕs′ĭv): A character possessed by one parent of a hybrid, not apparent in the hybrid but which may be transmitted to the descendants.
reclamation (rĕk′lȧ-mā′shŭn): Act of making something useless into something useful; land is reclaimed by drainage or by irrigation.
rectifier (rĕk′tĭ-fī-ẽr): A device for changing alternate into direct current.
reforestation (rē-fŏr-ĕs-tā′shŭn): Planting forests upon areas from which forests have been removed.
relay (rê-lā′): An electromagnetic device for closing a local circuit.
resistance (rê-zĭs′tăns): The opposition offered by a body to the flow of electricity through it.
retting (rĕt′ĭng): The process of preparing flax for use by soaking in water to remove the softer tissues.

sanitarium (săn′ĭ-târ′ĭ-ŭm): An establishment for the treatment of the sick.
Saturn (săt′ẽrn): A planet.
smelting (smĕlt′ĭng): To separate metal from ore.
spectroscope (spĕk′trô-skōp): An instrument for producing spectra.
sphagnum (sfăg′nŭm): Peat or bog moss.
stamen (stā′mĕn): The part of a flower which contains the pollen.
stereoscope (stĕr′ê-ô-skōp′): A device for looking at two pictures which merge into one.
sterilized (stĕr′ĭ-līzed): Freed from living disease bacteria.
stomata (stō′mȧ-tȧ): Plural of stō′mȧ, minute openings in the epidermis of leaves.
stratus (strā′tŭs): A cloud distinguished by great horizontal extent and low altitude.

stucco (stŭk′ō): A coating of plaster, generally on the outside of a building.

thermograph (thûr′mō̇-grȧf): An instrument keeping a continuous record of temperatures.

tornado (tôr-nā′dō): A funnel-shaped cloud with violent whirling winds.

toxin (tŏk′sĭn): A poisonous substance produced by disease-producing bacteria during their growth.

transformer (trăns-fôr′mẽr): A device for changing electric current from high to low or low to high voltage without changing the current energy.

transmission (trăns-mĭsh′*ŭ*n): Machine parts by which power is carried from the engine to the driving axles and wheels of the automobile.

transpiration (trăn′sp*ĭ*-rā′sh*ŭ*n): The giving out of water from the surface of green tissues in plants.

triangulation (trī-ang′gū̇-lā′sh*ŭ*n): The measurement of certain triangles to determine distance of various stars from the earth.

trypanosoma (trĭp′*ȧ*-nō̇-sō′m*ȧ*): A microscopic animal, that causes disease.

tsetse (tsĕt′sĕ): A fly that by its bite conveys to various animals the parasite (Trypanosoma) that causes nagana (similar to sleeping sickness).

tuberculosis (tū̇-bûr′kū̇-lō′sĭs): An infectious disease of the lungs.

turbine (tûr′bĭn): A special type of water wheel; a special type of steam engine.

Uncompahgre (ŭn′kŏm-pä′grĕ): A peak in the Rocky Mountains.

Uranus (ū′r*ȧ*-n*ŭ*s): A planet.

vaccination (văk′s*ĭ*-nā′shŭn): Process of introducing in a person a mild form of disease by use of weakened or dead germs or the products from these germs.

vaccine (văk′sĭn): Any substance used in vaccination.

vibroplex (vī′brō̇-plĕks): A modern telegraph key.

vivarium (vī-vâr′ĭ-*ŭ*m): A place arranged for keeping animals.

volatile (vŏl′*ȧ*-tĭl): Readily changing to a gas.

Welsbach mantle (wĕlz′băk): A mantle of non-combustible chemicals which give a bright white light when heated in a gas flame.

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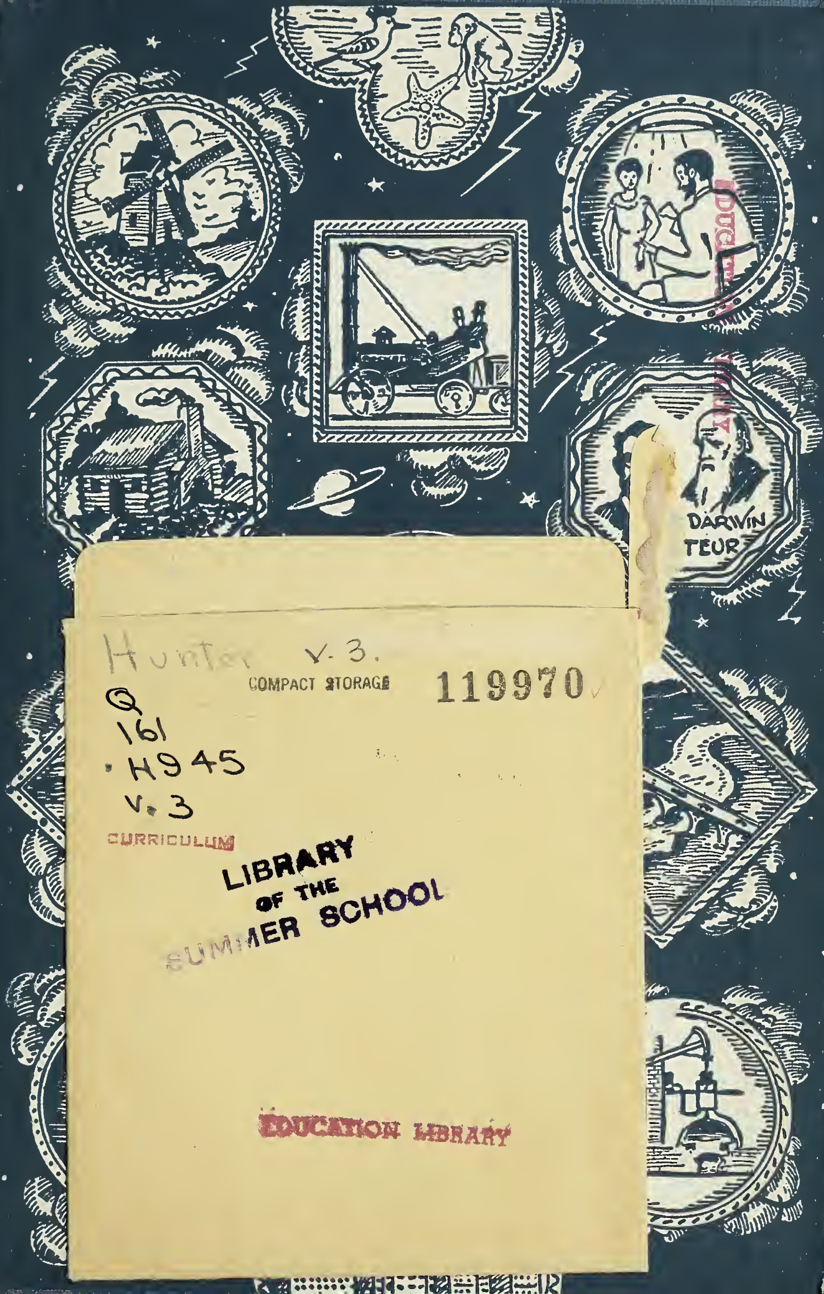
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